D4.3 Report on pilot case study 3

MAIL: Identifying Marginal Lands in Europe and strengthening their contribution potentialities in a CO2 sequestration strategy

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ABBREVIATIONS

Term	Explanation
AGB	Above-Ground Biomass
BCEF	Biomass Conversion and Expansion Factors
$BCEF_S$	Biomass Conversion and Expansion Factors of merchantable growing stock volume to above-ground biomass
BTU	British Thermal Unit
CF	Carbon Fraction
0DBH	Diameter at breast height (cm)
Dg	Mean square diameter (cm)
dM	Thick log diameter (cm)
dm	Thin log diameter (cm)
G	Basal area (m^2 per hectare)
GDP	Gross domestic product
GVA	Gross value added
Hm	Mean stand height (meters)
H_o	Dominant stand height (meters)
HWPs	Harvested Wood Products
IPCC	Intergovernmental Panel on Climate Change
L	Log length (m)
MLs	Marginal Lands
MS	Member State

N	Number of trees per hectare
SI	Site Index
Vol	Stand tree wood volume (m^3 per hectare)
Vol+bark	Stand tree wood and bark volume (m^3 per hectare)

Contents

EXECUTIVE SUMMARY

At this report an analysis of the estimation of carbon stock in forest products is taking place, in the content of harvested timber. Wood is converted to products where the carbon content is remaining stored though the product's life time. While the product is changing use/ form the carbon is still stored and is emitted to the atmosphere only when it is burned or deposited in landfills where they slowly decay.

In **chapter 1** the basic goals of this Task are presented.

In **chapter 2** the basic types and characteristics of wood products are described, according to the Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018, taking into account the IPCC Guidelines. At a second level the wood products are described in more detail for the four Member States (MS) that participate in the project; Germany, Greece, Poland and Spain.

In **chapter 3** the methodology that is used for carbon calculation in wood products is described. Specific species were selected for each country, based on ecological zones and sites quality, for possible afforestation projects in the detected marginal lands of T2.3. After literature review, proper existing yield tables were selected in order to predict wood growth over time. Based on that, specific periods of thinnings were defined per country and species. The carbon stock of these Harvested Wood Products (HWP) was then estimated based on the destination of the harvested wood from MLs plantings.

In **chapter 4** the lifespan of wood products from MLs is described. Once the amount of forest product has been calculated, the useful life of these products can be calculated with the equation included in ANNEX III of European Decision 529/2013. These HWPs were assigned specific average half-life values; 2 years for paper, 25 years for wood panels and 35 years for sawn wood. A further analysis per participating MS was implemented, based on the previous findings.

In **chapter 5** a market study in primary wood-processing industries is presented based on statistics of EU-27 in a European level and in participating MS also.

At the end in **chapter 6** summary and conclusions are presented, based on the findings of this report.

1. INTRODUCTION AND GOALS OF TASK 4.3

Wood products are considered to contribute to the mitigation of carbon emissions, through either by storing wood-based carbon or by substituting environmentally unfriendly, in terms of their renewal ability, sources of material and energy such as concrete for construction and fossil fuels.

Harvested timber can be converted into a wide range of wood products with their carbon content moving through different levels during their life cycle. After their use, wood products may become recycled, and ultimately burned or deposited in landfills where they slowly decay. The carbon stored in wood, which was initially captured from the atmosphere, is finally released back into the atmosphere. Changing the demand for wood products can consequently have an important role in the global carbon cycle and the fight against climate change.

Incentives to increase the use of Harvested Wood Products (HWPs) are implicitly provided in the Kyoto Protocol, as substituting fossil fuels with wood-based fuels and energy intensive materials with wood-based products is a mean to reduce carbon dioxide emissions.

The 2006 IPCC guidelines and their recent refinement (2019) provide guidance on how to estimate and report the contribution of HWPs to annual CO2 emissions/ removals. HWP is normally reported by product categories with different life-cycles such as paper, wood panels and sawn wood and include emissions from the decay of existing HWPs and the increase in carbon stocks through addition of new HWPs. However, the national carbon pool of HWPs is very dynamic, due to changing patterns of wood product consumption and trade.

The present Task will identify and quantify the carbon in forest products in MLs referred as HWPs. Firstly, types of wood products existing in MLs, i.e., saw wood, pulpwood for board and pulpwood for energy use will be outlined and then CO2 stored in these products will be quantified.

In this task the following actions were performed:

- Allocation and identification of the forest areas. For that, a Land Cover Land Use Analysis was performed for the identification of the forest species in close vicinity to the pilot sites at the Southern and Central European pilot scale. This allows understanding of the reforestation module in the MLs pilot scale.

-Calculation of the carbon stored in each wood product in MLs through the estimation of future biomass. In respect with the reforestation modules at each pilot area a review of growth models and assessment of which models are the most suitable to study the evolution of the non-forested MLs into forested MLs was realized. Then calculation of the final biomass destined to each wood product using the output of the model and the relationship of between diameters and use was performed as well as of the carbon fixed by the wood product.

- Finally, a bibliographic review on wood market trends was pursued so as to demonstrate how much carbon remains stored as a timber forest product in the country of the pilot site.

In this regard, the document focuses on:

1. Identification and allocation of the future forest species in MLs pilot areas under projected reforestation modules
2. Calculation of the carbon stored in wood products
3. Check and adjust all the quantification of carbon products

2. Wood products in MLs

2.1 Types and characteristics of wood products

2.1.1 Regulation (EU) 2018/841

According to the Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU the different types of wood products are grouped as following:

(a) paper;

(b) wood panels;

(c) sawn wood.

These categories can be further broadened depending on the country. For the sake of commodity, we will follow these three.

In Article 9 of the same Regulation accounting for harvested wood products Member States shall reflect emissions and removals resulting from changes in the carbon pool of harvested wood products falling within the following categories using the first order decay function, the methodologies and the default half-life values specified in Annex V and outlined below:

First order decay function, methodologies, and default half-life values for harvested wood products

Methodological issues

- If it is not possible to differentiate between harvested wood products in the land accounting categories of afforested land and managed forest land, a Member State may choose to account for harvested wood products assuming that all emissions and removals occurred on managed forest land.

- Harvested wood products in solid waste disposal sites and harvested wood products that were harvested for energy purposes shall be accounted for on the basis of instantaneous oxidation.

- Imported harvested wood products, irrespective of their origin, shall not be accounted for by the importing Member State (‘production approach’).

- For exported harvested wood products, country-specific data refer to country-specific half-life values and harvested wood products usage in the importing country.

- Country-specific half-life values for harvested wood products placed on the market in the Union should not deviate from those used by the importing Member State.

- Member States may, for information purposes only, provide in their submission data on the share of wood used for energy purposes that was imported from outside the Union, and the countries of origin for such wood.

Default half-life values:

Half-life value means the number of years it takes for the quantity of carbon stored in a harvested wood products’ category to decrease to one half of its initial value.

Default half-life values shall be as follows:

(a) 2 years for paper;

(b) 25 years for wood panels;

(c) 35 years for sawn wood.

2.1.2 IPCC Guidelines (2019)

The following three aggregate commodities of semi-finished wood products, by definition, represent data on wood being processed with the intention of using the wood as a material to make products. The definitions given are those designated by FAO (2017).

Paper and paperboard: “The paper and paperboard category is an aggregate category. In the production and trade statistics, it represents the sum of graphic papers; sanitary and household papers; packaging materials and other paper and paperboard. It excludes manufactured paper products such as boxes, cartons, books, and magazines, etc.

Wood-based panels: "This product category is an aggregate comprising veneer sheets, plywood, particle board, and fiberboard. Wood-based panels covers different products which have been used for the divisions definition, such as plywood, particle board, oriented strandboard (OSB), fiberboard, densified wood, combination board and other panels based on other ligno-cellulosic materials. Different approaches have been used for the classification of the main products included in the divisions, e.g. technology used in the production process (production process type), tree-species origin, wood panel density, final product, among others.

Sawn wood: "Wood that has been produced from both domestic and imported roundwood, either by sawing lengthways or by a profile-chipping process and that exceeds 6 mm in thickness. It includes planks, beams, joists, boards, rafters, scantlings, laths, boxboards, and "lumber", etc., in the following forms: unplanned, planned, end-jointed, etc. It excludes sleepers, wooden flooring, mouldings (sawnwood continuously shaped along any of its edges or faces, like tongued, grooved, rebated, V-jointed, beaded, moulded, rounded or the like) and sawnwood produced by re-sawing previously sawn pieces.

Moreover, HWP feedstock commodity classes serving as fuel wood and raw material for manufacturing of semi-finished HWP, especially in MLs, such as:

Wood chips and particles: "Wood that has been reduced to small pieces and is suitable for pulping, for particle board and/or fiberboard production, for use as a fuel, or for other purposes. It excludes wood chips made directly in the forest from roundwood (i.e. already counted as pulpwood or wood fuel). It is reported in cubic meters solid volume excluding bark".

Wood residues: "Other wood processing co-products. It includes wood waste and scrap not useable as timber such as sawmill rejects, slabs, edgings and trimmings, veneer log cores, veneer rejects, sawdust, residues from carpentry and joinery production, and wood residues that will be used for production of pellets and other agglomerated products. It excludes wood chips, made either directly in the forest from roundwood or made in the wood processing industry (i.e. already counted as pulpwood or wood chips and particles), and agglomerated products such as logs, briquettes, pellets or similar forms as well as post-consumer wood. It is reported in cubic meters solid volume excluding bark"

2.2 Characteristics of the wood products

The main components for assessing wood quality for structural purposes are strength, stiffness, and dimensional stability, while pulp and paper quality requirements include strength, tracheid dimensions and chemical composition. The quality of wood is determined through various wood characteristics such as: density, microfibril angle, proportion of juvenile wood, fibre length, compression wood and knots.

In the production of pulp and paper, low density wood combined with long fibres results in collapsible, easy bonding fibres that exhibit low porosity and high strength. These fibre characteristics result in higher quality paper products. Conversely, structural lumber manufacturing requires wood with high density, small knots, and straight grain characteristics to ensure a high-quality product (Joza & Middleton, 1994). Also, the stiffness, or modulus of elasticity (MOE), is an important characteristic associated with the structural quality of lumber (Johnson & Gartner, 2006). The raw material requirements for plywood prioritize the same characteristics used in determining wood quality for lumber products.

The diameter of the log is one of the variables that most determines the use of wood and performance in transformation and this why in this deliverable special focus will be given on quality characteristics of the wood in relation to the log diameter.

2.2.1 Germany

On Germany some rules and normatives are used as a standard to guide. The EN1927 for Scots pine (*Pinus sylvestris*), where the main quality parameters are the thick and thin tip diameter of the log (dM & dm), its minimum length L (M) and the quality class, because of the lack of information and scientific data for the *Picea abies,* the same information about diameters was considered as relevant to this study as can be seen on the Table 1.

Table 1 - Quality characteristics of *Pinus sylvestris* roundwood placed at the factory and their use

Use	Correspondence with Regulation (EU) 2018/841 wood products categories	dm (cm)	dM (cm)	L (m)	Quality class
Flat veneer	Wood-based panels	45	-	2,6	A
Sawn wood for carpentry and furniture	Sawn wood	25	-	2,5	A-B
Posts	Sawn wood	10	30	6	B
Stakes, fences	Sawn wood	7,5	12,5	1,5	B
Sawn wood auxiliary construction	Sawn wood	20	-	2,5	C
Sawn wood containers and pallets	Sawn wood	15	-	1,2	C
Particleboard, fiberboard and pulp	Paper and paperboard	6	40	2	D

2.2.2 Greece

In Greece, two wood categories are defined:

a. The industrial wood that includes:

- The timber of structures, which is also called "round timber", technical timber or technical wood, and includes relatively large logs (up to 15 m long and usually over 20 cm in diameter) intended for sawing but also for other uses (e.g. timber for mines, boxes, floors, matches, sawn timber, telecommunication poles etc.), and

- Crushing wood (or industrial wood), which is used after its conversion into crushed particles for particle board, fiberboard and paper. In this case the wood is short (0,80-1.20 m) and can be round (6-35 cm in diameter) or split.

b. firewood that are pieces, round or split, of length 0,80-1,50 m and diameter > 5 cm, which are not included in the above categories and are intended for household needs (heating, cooking, etc.).

According to Greek Decision 30661/816 (16.04.2020) for the Forest Products Pricing Table for 2020 management year, the prices for round wood are established according to the quality parameters: mean diameter of the log (d) and its length L (M) for softwood (Table 2) and hardwood (Table 3) respectively.

Table 2. Destination of wood (of softwood species) according to its dimensions in Greece

Use	Correspondence with Regulation (EU) 2018/841 wood products categories	dm (cm)	L (m)	Price per m^3, €
Thick Roundwood of large length (*Pinus sylvestris, Pinus nigra, Pinus halepensis, Pinus brutia, Pinus heldreichii, Picea abies*)	Sawnwood	>20	>2	63,4-43,4
Thick Roundwood of small length (*Pinus sylvestris, Pinus nigra, Pinus halepensis, Pinus brutia, Pinus heldreichii, Picea abies*)	Sawnwood	>20	<2	36,5-21,3
Thin Roundwood	Sawnwood	10-20	>3	36,5
Thin Roundwood	Sawnwood	6-10	>2,5	39,3
Power transmission poles	Sawnwood	9-15	19-32	84,3
Telecommunication poles	Sawnwood	5,5-8	12,5-19	79,2
Split pine wood (pieces)	Sawnwood *(or Fuelwood)*	-	-	18,9
Disintegration of wood into sawdust	Wood-based panels	-	-	13,9
Firewood		-	-	14,3
Charcoals		-	-	0,25

Table 3. Destination of wood (of hardwood species) according to its dimensions in Greece

Use	Correspondence with Regulation (EU) 2018/841 wood products categories	dm (cm)	L (m)	Price per m^3, €
Roundwood (*Castanea sativa, Fagus spp., Quercus ilex, Ostrya carpinifolia*)	Sawnwood	>20	>1,8	60,9-45,1
Roundwood of poplar plantings *(Populus sp.)*	Sawnwood	>25	>1	56,2
Roundwood regardless of length *(Fraxinus ornus, Acer spp., Tilia spp.)*	Sawnwood	>25		65,1-58,9

		<25		40,2-40
Roundwood regardless of diameter *(Juglans sp.)*	Sawnwood			136,2-61,8
Power transmission poles	Sawnwood	9-15	19-32	81,9
Telecommunication poles	Sawnwood	5,5-8	12,5-19	53,1
Round wood (pieces) (*Fagus sp., Castanea sativa)*	Sawnwood	>25		48,1-33,3
		<25		31,8-25,2
Round wood (pieces) *(Populus sp.)*	Sawnwood	15-25		24,4
Round wood (pieces) regardless of diameter	Sawnwood *(or Fuelwood)*	-	-	35,2-27,6
Split wood (*Fagus sp., Castanea sativa)*	Sawnwood *(or Fuelwood)*	-	-	35,2-27,6
Disintegration of wood into sawdust *(Fagus sp., Populus sp.)*	Wood-based panels	-	-	12,5-18,9
Fuelwood (*Fagus sp., Castanea sativa, Populus sp., Quercus sp.)*		-	-	29,2-21,3
Charcoal *(Fagus sp., Quercus sp.)*		-		0,5-0,3

Brutia pine (*Pinus brutia* Ten.) being an indigenous, drought resistant and soil tolerant conifer species has been widely used for reforestation of depleted lands in Greece (Hatzistathis et al. 1995). The main purpose of planting brutia pine was to protect and improve soils, rather than grow trees for wood utilisation (Roussodimos & Petinarakis 1994). The high proportions of knots and reaction wood make brutia pine timber suitable for pallets, box-making and chip production and infrequently for high value products for joinery, furniture, construction and boatbuilding. Timber from *Pinus brutia* is used for fencing posts, telephone posts, building timbers, railway sleepers, carpentry, boxes and crates, hardboard and pulp. Defect free brutia pine wood has been proved to possess good technological properties that make it ideal for construction uses that require strength and durability (Roussodimos & Petinarakis

1994). Information on wood density and annual ring components are limited for *P. brutia*. Adamopoulos et al. (2009) studied the ring width, latewood proportion, and dry density of 16 dominant *P. brutia* trees randomly chosen from two reforestation sites in Northeastern Greece.

Information on assorting categories of wood products in relation to quality properties of the wood such as the log diameter or length are not sufficiently recorded in Greece. This is due to the fact that Greek forests are mainly natural forests (96%) and less plantations (4%). Even though natural forests are managed with final clear-cuttings providing wood for fuel in most of the times, in general, market demand for wood products from Greek forests in limited. The quality of harvested wood demonstrates disadvantages such as large percentage of immature wood, wide annual rings, and lots of defects (knots, compression wood).

Forest area by wood species in Greece is represented as part of total area for Softwoods with *Abies spp.* (8.5%), *Pinus brutia* (9.1%), *Pinus nigra* (4.4%) and for Hardwoods with *Fagus sylvatica* (5.2%), *Quercus sp*. (22.6%) and other coppice broadleaves (48.4%) (Mantanis, 2011). The annual production of Greek forests accounts for three categories of wood products; Roundwood, Industrial wood and Fuelwood, as shown in Table 4.

Table 4.Annual production of Greek forests (in m3) depending on wood products category (Mantanis, 2011).

Categories of wood products	Type of wood	Annual production (in m^3)
Roundwood	Softwoods	248,000
	Hardwoods	133,000
Industrial wood (wood going for particleboard & MDF)	Softwoods	48,500
	Hardwoods	39,500
Fuelwood	Softwoods	64,000
	Hardwoods	693,000

Bluestain in black pine is a serious problem. Also, due to soil and steep forests, timber contains much of compression wood. Fir and black pine wood contain high number of knots and its quality is rather low.

2.2.3 Poland

In Table 5 parameters of timber assortment types used for stem wood classification in *Pinus sylvestris* are presented for Poland (Węgiel et al., 2018).

Table 5. Parameters of timber assortment types used for stem wood classification in *Pinus sylvestris* in Poland

Type of timber assortment	Symbol	Correspondence with Regulation (EU) 2018/841	Middle diameter* (cm)	Small-end diameter* (cm)	Length (m)	Price per m^3, €*
Sawmill wood third thickness class	SM3	Sawnwood	≥ 35	≥ 14	2,5	65,0
Sawmill wood second thickness class	SM2	Sawnwood	25–34	≥ 14	2,5	56,9
Sawmill wood first thickness class	SM1	Sawnwood	≤ 24	≥ 14	2,5	48,8
Pulpwood	PW	Paper and paperboard	-	≥ 5	2,5	38,1
Energy wood (stem residuals)	EW		-	-	-	13,6

EW: Energy wood; PW: Pulpwood; SM1: Sawmill wood of first thickness class (mid-diameter up to 24 cm under bark); SM2: Sawmill wood of second thickness class (mid-diameter between 25 and 34 cm under bark); SM3: Sawmill wood of third thickness class (mid-diameter 35 cm and higher under bark) * under bark

2.2.4 Spain

The most common destinations of wood in Spain are given in Table 6, based on the thick and thin tip diameter of the log (dM & dm) and its minimum length L (M) according to Vignote et al (2006).

Table 6. Destination of wood according to its dimensions in Spain (Vignote et al, 2006)

Use	Correspondence with Regulation (EU) 2018/841 wood products categories	dm (cm)	dM (cm)	L (m)
Pit props	Sawn wood	8	15	2,5

Stakes, fences	Sawn wood	8	15	1,5
Disintegration of wood into sawdust	Wood panels	6	35	1
Posts	Sawn wood	10	45	6
Sawn wood for carpentry and furniture	Sawn wood	20	200	2
Sawn wood auxiliary construction	Sawn wood	20	100	2,4
Sawn wood containers and pallets	Sawn wood	15	40	1,2
Flat veneer and plywood from unrolling	Wood-based panels	35	160	2,6

Table 7 includes the classification of wood products in Spain based on the norm of UNE 56514:85. A more specific classification was made through the development of CUBIFOR tool in Castille & Leon of Spain, where the user may perform a calculation of timber volume in the different wood products, of the forest biomass, as well as a quantification of the CO_2 fixed by forests of this area.

Table 7. Classification of wood products according to log dimensions based on the UNE 56514:85 norm

Use	Correspondence with Regulation (EU) 2018/841 wood products categories	dm (cm)	dM (cm)	L (m)
Plywood through unrolling	Wood-based panels	15	160	0,6
Sawn wood	Sawn wood	20	200	1,2
Posts	Sawn wood	10	45	6
Disintegration of wood into sawdust	Wood panels	8	20	1
Props	Sawn wood	8	15	2,5

Although the variability of the physical-mechanical characteristics is very small, the price that a wood can reach depending on its quality characteristics is very high. Thus, Vignote et al (2006) establishes the prices indicated in Table 8 for roundwood from Scots pine (*Pinus sylvestris*), where the main quality parameters are the thick and thin tip diameter of the log (dM & dm), its minimum length L (M) and the quality class in accordance with EN 1927.

Table 8. Quality characteristics of *Pinus sylvestris* roundwood placed at the factory and their use

Use	Correspondence with Regulation (EU) 2018/841 wood products categories	dm (cm)	dM (cm)	L (m)	Quality class	Price (€/m^3)
Flat veneer	Wood-based panels	45	-	2,6	A	425
Sawn wood for carpentry and furniture	Sawn wood	25	-	2,5	A-B	75
Posts	Sawn wood	10	30	6	B	50
Stakes, fences	Sawn wood	7,5	12,5	1,5	B	50
Sawn wood auxiliary construction	Sawn wood	20	-	2,5	C	46
Sawn wood containers and pallets	Sawn wood	15	-	1,2	C	40
Particleboard, fiberboard and pulp	Paper and paperboard	6	40	2	D	33

3. Methodology: Carbon calculation in wood products

3.1 Land Cover Land Use Analysis:

3.1.1 Allocation and identification of the forest areas

Pilot sites were identified in Germany, Greece, Poland and Spain for the project implementation. The species already growing in each surrounding area were examined and those most suitable for the demanding conditions in MLs were selected for planting. More details on the selection of the pilot sites and species are given below for each country.

3.1.1.1 Germany

The species selection in the Germany pilot sites was performed using the information provided by the National Inventory carried out in 2011/2012. This inventory presents the species cover area of specific states and regions in Germany. As showed with details in the Task 4.2 the areas of interest that will be considered and used as pilot sites are the municipality of Welzow, which is in the estate of Brandenburg and the Sachsen (Saxony).

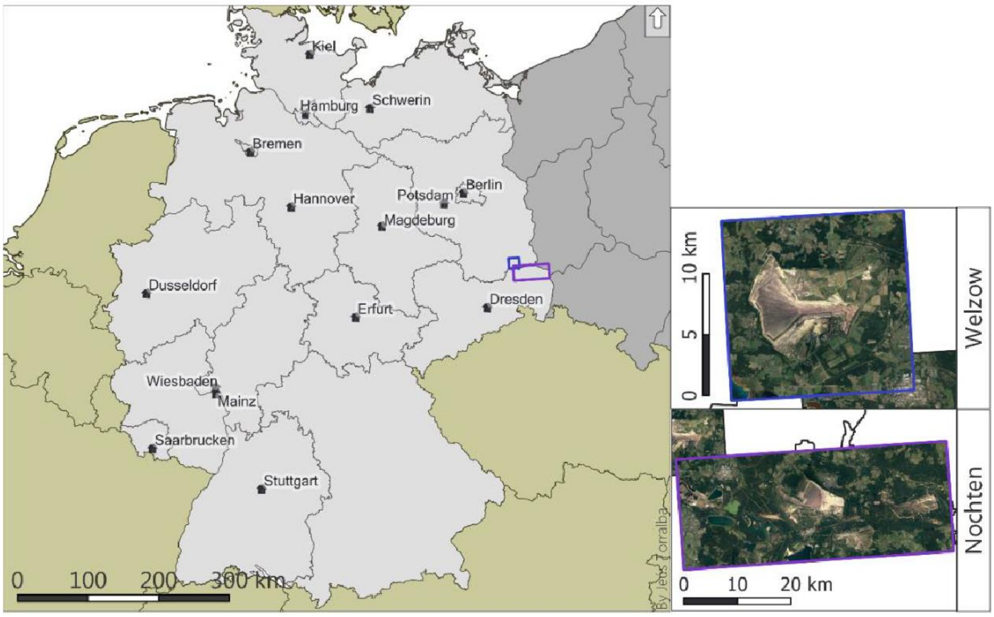


Figure 1. Germany (left) and the pilot sites of "Welzow" (outlined with blue) and "Nochten" (outlined with purple).

Based on the forest inventory mentioned before, the two most representative species in the areas are the *Pinus sylvestris* and the *Picea abies* (Table 9). These two species are the ones considered and used in the reforestation of the pilot sites, which will be more well be presented with more details in the following sections.

Table 9. Area distribution for the main species in the German landers of Brandenburg + Berlin and Sachsen.

Land	**Brandenburg + Berlin**	**Sachsen**	**Germany (all Länder)**
Measure	*%*	*%*	*%*
Oak	6.59	8.59	10.38
Beech	3.30	4.23	15.43
Other deciduous trees with a long life expectancy	3.35	4.09	7.07
Other deciduous trees with a short life expectancy	11.28	14.59	10.54
All deciduous trees	24.52	31.50	43.42
Spruce	1.80	34.38	25.38
Fir	0.00	0.15	1.68
Douglas fir	0.97	0.20	2.00
Pine	70.14	28.20	22.31
Larch	1.17	3.42	2.82
All coniferous trees	74.07	66.35	54.19
Gap	1.18	1.67	2.02
Temporarily unstocked area	0.22	0.48	0.38
All tree species	100	100	100

3.1.1.2 Greece

The pilot sites selected in Greece share the same marginality conditions as the Spanish ones; they are low productivity lands adjacent to natural parks and forest areas. The test sites are two and located in the region of Macedonia and Thrace. One in Thessaloniki prefecture at the mountainous areas above “Thermi” and “Vassilika” and one in Rhodope prefecture and more specifically at the mountainous areas of “Proskynites” and “Xylagani” southern of Komotini. Part of Thessaloniki’s pilot case is “Isenli” forest, where HOMEOTECH had implemented the management plan for the period 2007 – 2016. Results and field data from that project were taken into account for better understanding the local marginal lands. The test sites are presented in Figure 2.

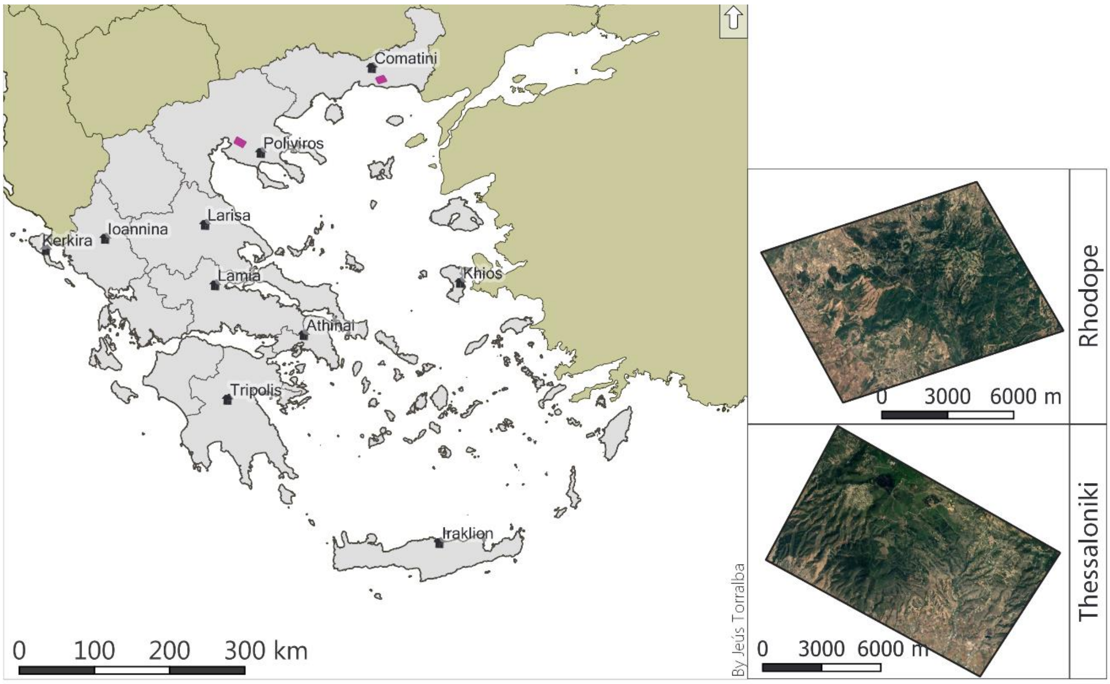


Figure 2. Greece (left) and the pilot site of the afforestation forest of "Rhodope" and "Thessaloniki".

For the Greek pilot sites, a composition of the national forest map and vegetation map of Isenli forest was used (Figure 2, Figure 3). This layer offers information about the structure and species composition for all the pilot sites in Greece as represented in the following tables (Table 10 and Table 11).

Thessaloniki

Regarding Thessaloniki the forested area covers 9.71% of the whole area where dominant species are *Pinus halepensis* and *Pinus brutia* (5.70%), both Mediterranean coniferous species adapted to scarce rainfall regimes, optimal for planting in MLs followed by *Quercus frainetto* (1.51%). Shrubs cover 62.94%, grasslands 3.22%, while barren lands are around 0.45%.

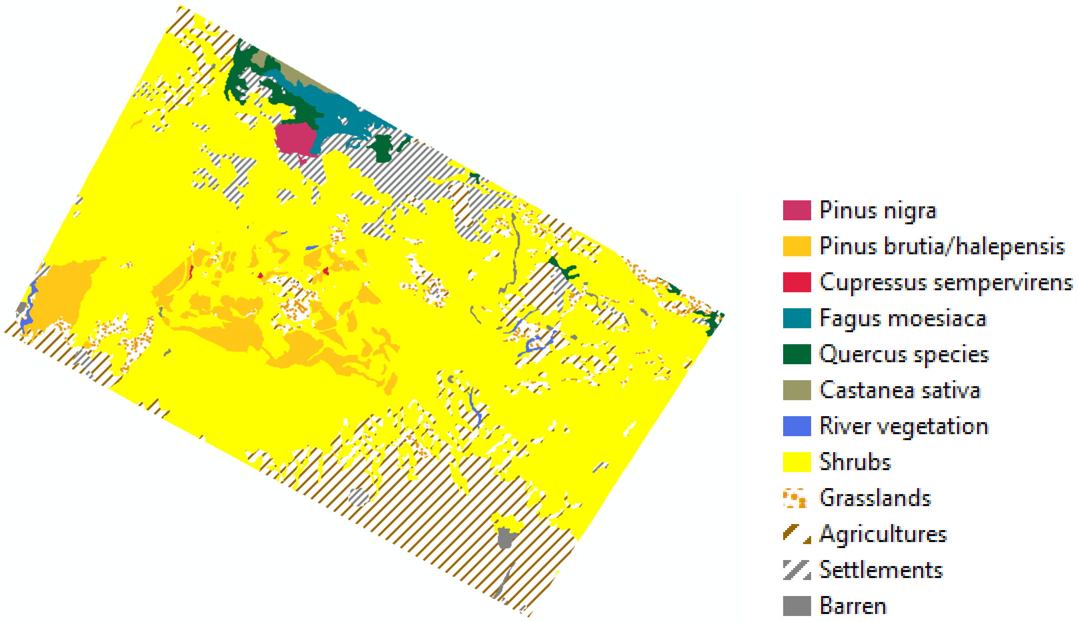


Figure 3. Vegetation map of Isenli forest

The vegetation is summarized in the following table (Table 10).

Table 10. Thessaloniki's test sites

Species	Area (Ha)	Percent (%)
Forest, *Castanea sativa*	30.05	0.31%
Forest, *Cupressus sempervirens*	3.56	0.04%
Forest, *Fagus moesiaca*	130.32	1.35%
Forest, *Pinus brutia*	287.53	2.98%
Forest, *Pinus halepensis*	262.54	2.72%
Forest, *Pinus nigra*	50.12	0.52%
Forest, *Quercus frainetto*	146.63	1.51%
Forest, side river vegetation	26.89	0.28%
Shrubs (evergreen and broadleaves)	6,082.40	62.94%
Grasslands	311.59	3.22%
Barren lands	43.30	0.45%
Agricultures	1,713.30	17.73%
Settlements	574.79	5.95%
Total	**9,663.02**	**100.00%**

Rhodope

Regarding Rhodope the forested area covers 12.54% of the whole area where dominant species are *Pinus halepensis* and *Pinus brutia* (12.29%), both Mediterranean coniferous species adapted to scarce rainfall regimes, optimal for planting in MLs followed by *Quercus frainetto* (0.18%). Shrubs cover 46.46%, grasslands 1.68%, while barren lands are around 0.09%.

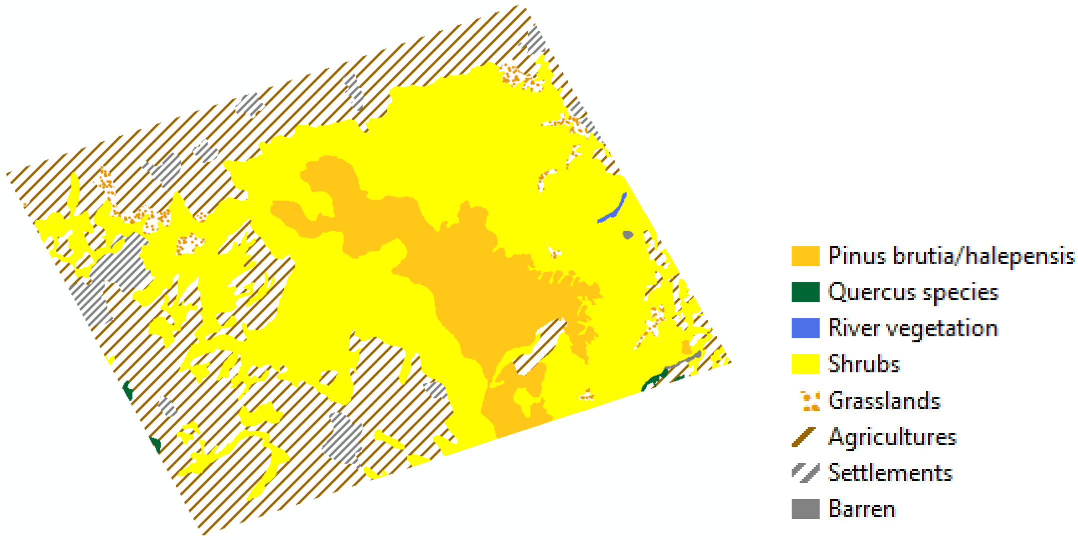


Figure 4. Vegetation map of Rhopode forest.

The vegetation is summarized in the following table (Table 11).

Table 11. Rhodope's test sites.

Species	Area (Ha)	Percent (%)
Forest, *Pinus halepensis*	982.50	12.29%
Forest, *Quercus frainetto*	14.10	0.18%
Forest, *side river vegetation*	5.85	0.07%
Shrubs (evergreen and broadleaves)	3,713.77	46.46%
Grasslands	134.09	1.68%
Barren land	7.09	0.09%
Agricultures	2,843.78	35.58%
Settlements	292.03	3.65%
Total	***7,993.21***	***100.00%***

Both pilot sites are in similar ecological zones and can facilitate afforestation projects either for conifers, such as *Pinus halepensis* either for deciduous broadleaves such as *Quercus frainetto*. Additionally, both species are present at both pilot sites, a fact that also indicates species suitability for reforestation modules.

3.1.1.3 Poland

For the Poland pilot sites, the region in the Staszow County part of Świętokrzyskie Voivodeship, called “Staszów” was selected. The whole region is divided into an industrial region, which is located on the north side, and a rural one, on the south part. According to the data, this area was devastated land and was increasing between 2004 – 2012. The region also includes upland and lowland, fragmented croplands, and low productivity lands which can be defined as potential Marginal Lands.

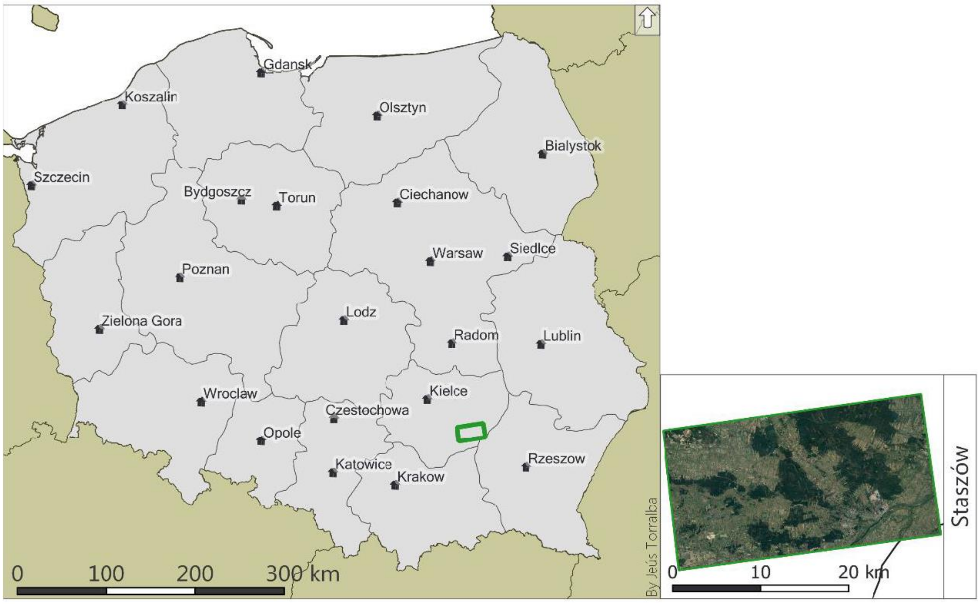


Figure 5. Poland (left) and the corresponding selected pilot site (outlined with green).

Based on the Polish National Inventory the species composition of the pilot site was analyzed. The spatially referenced data provide the composition of each plot. The table below represents the species composition of the area as can be seen on the Table 12:

Table 12. Area distribution for the main species in the Polish test site according to the Polish Forest Data Bank.

Specie CD	Scientific name	Area [ha]	%	Frequency
SO	*Pinus sylvestris*	7,101.43	76.67	2271
DB	*Quercus species*	1,031.29	11.13	301
OL	*Alnus glutinosa*	538.84	5.82	260
BRZ	*Betula pendula*	253.70	2.74	124
JD	*Abies alba*	90.16	0.97	28
BK	*Fagus sylvatica*	63.10	0.68	17
MD	*Larix decidua*	49.66	0.54	16
DB.S	*Quercus robur*	23.78	0.26	7
OS	*Populus tremula*	22.83	0.25	18
ŚW	*Picea abies*	22.07	0.24	23
DB.C	*Quercus rubra*	15.67	0.17	7
GB	*Pyrus communis*	11.62	0.13	9
WB	*Salix alba*	8.43	0.09	6
DB.B	*Quercus petraea*	7.56	0.08	4
KRU	*Rhamnus frangula*	7.01	0.08	8
AK	*Robinia pseudoacacia*	4.00	0.04	6
ŚL.T	*Prunus spinosa*	3.60	0.04	5
JS	*Fraxinus excelsior*	3.39	0.04	3
JW	*Acer pseudoplatanus*	1.47	0.02	2
LP	*Tilia cordata*	1.41	0.02	3
KL	*Acer platanoides*	0.73	0.01	1
CZM	*Prunus padus*	0.27	0.003	1
DG	*Pseudotsuga menziesii*	0.26	0.003	1
TP	*Populus alba*	0.13	0.001	1
	Total	**9,262.40**	**100**	**3,122**

Based on the table and on the Figure 6 is possible to see that there's a high diversity related to the forest species composition on the pilot site, with a total of 24 species.

However, only 3 species are considered as the ones which most represent and describe the study area. As the *Pinus sylvestris*, being the dominant one, and also the *Quercus* species (as the *Q. patraea, Q. robur* and *Q. rubra), and finally the Alnus glutinosa*.

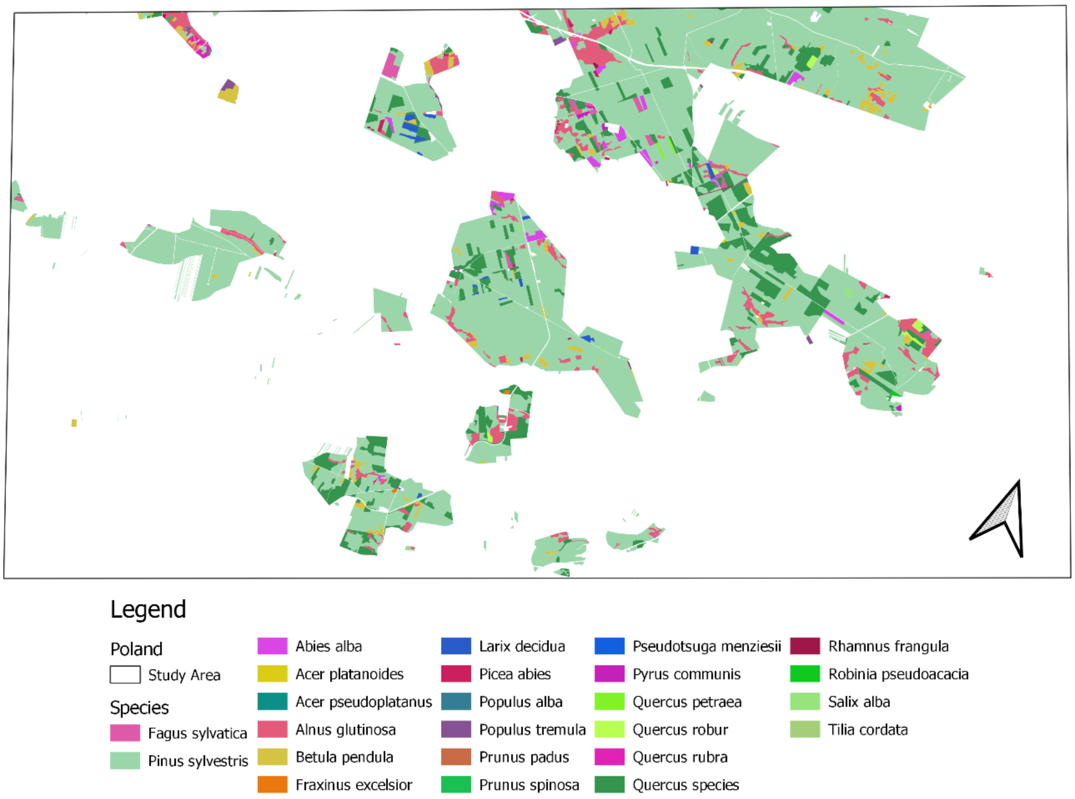


Figure 6. Species distribution in the Polish test site according to the Polish Forest Data Bank.

3.1.1.4 Spain

The Marginal lands proposed for Spain consist of several potential sites that could be defined as Marginal Lands including semi-urban degraded lands and low productivity lands adjacent to natural parks and forest areas. The test sites are “Tierras altas”, which is located in Soria province of Castilla y León, the area of the Municipality of Nogueruelas (Teruel) in the Central Eastern part of the Iberian Peninsula and “Sierra de Espadán” in the province of Castellón (region of Valencia) see Figure 7 .

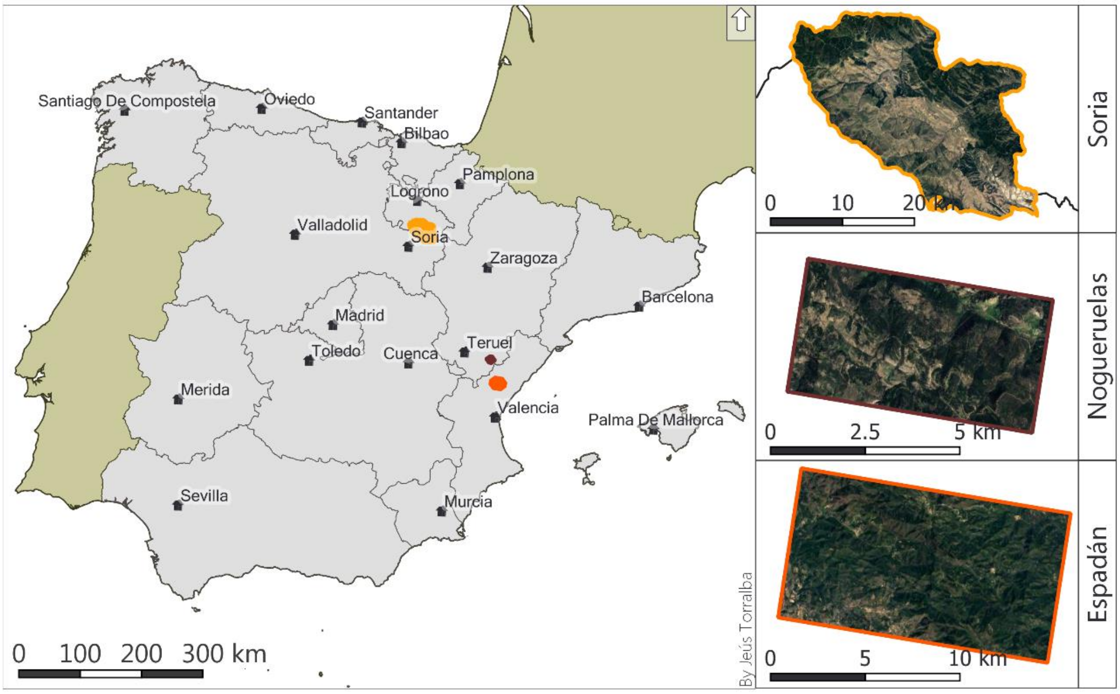


Figure 7. Spain (left) and the pilot site of "Soria" (outlined with light orange), "Nogueruelas" (outlined with dark red) and "Espadán" (right image outlined with dark orange).

For the Spanish pilot sites, the national forest map was used. This layer offers information about the structure and species composition for all the forest areas in Spain represented in tiles. For each pilot site the current species composition was analyzed, and the most frequent species were selected for the reforestation module.

Soria: Tierras Altas

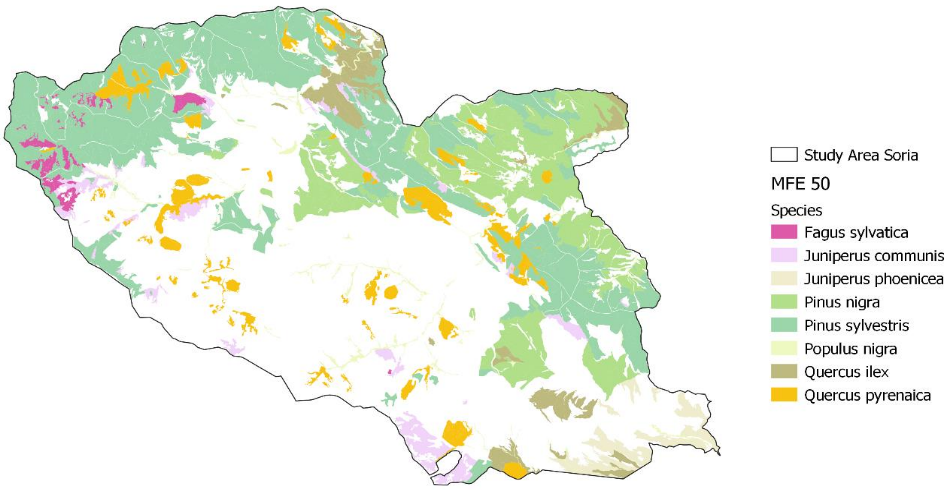


Figure 8. Species distribution for Tierras Altas, Soria. Source MFE50.

The species occurrence is summarized in the next table:

Table 13. Area distribution for the main species in Tierras altas, Soria according to the MFE50.

Species	Area ha	Area %	Frequency
Crataegus monogyna	29.91	0.11%	1
Fagus sylvatica	552.46	1.95%	35
Ilex aquifolium	304.50	1.08%	12
Juniperus communis	1,307.99	4.62%	47
Juniperus oxycedrus	39.25	0.14%	2
Juniperus phoenicea	962.30	3.40%	23
Juniperus thurifera	47.82	0.17%	1
Pinus nigra	6,431.56	22.71%	151
Pinus pinaster	14.66	0.05%	2
Pinus sylvestris	13,410.31	47.36%	313
Populus nigra	668.71	2.36%	47
Populus x canadensis	65.31	0.23%	3
Prunus avium	2.79	0.01%	1
Quercus faginea	117.68	0.42%	5
Quercus ilex	1,853.43	6.54%	64
Quercus pyrenaica	2,484.21	8.77%	117
Salix fragilis	9.33	0,03%	1
Salix spp.	16.36	0.06%	2
Total	**28,318.59**	**100.00%**	**827**

Table 13 reflects that the most represented species in the Sorian test site area are: *Pinus sylvestris, Pinus nigra* and *Quercus pyrenaica.* Although *Quercus pyrenaica* is representative of the study area, the fact that it is more resource demanding than the conifer species present in the test site, deems this species as a less suitable candidate for entering in the restoration module.

Castellón: Sierra de Espadán

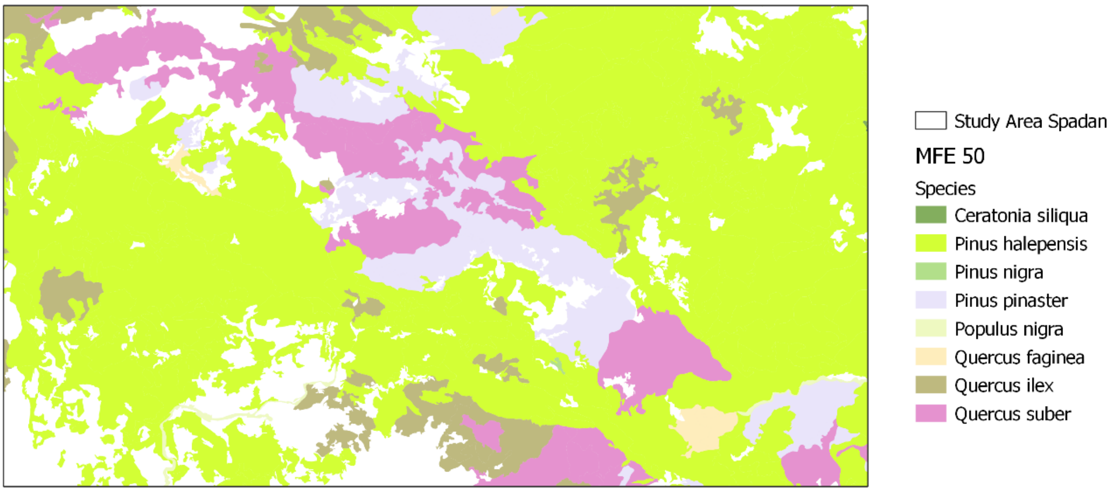


Figure 9. Species distribution in Sierra de Espadán, Castellón. Source MFE50.

The test site in la Sierra de Espadán is characterized by the presence of coniferous species, mainly represented by *Pinus halepensis* (70%) and *Pinus pinaster* (10%), while broadleaves species are constituted by *Quercus suber* (12,30%) and *Quercus ilex* (6,41%). As previously argued before in Soria test site (Tierras Altas), the marginal lands located in the Spanish Mediterranean sites are originated by environmental limitations rather than economic or social. Therefore, the species selection must prioritize the most resistant species to adverse ecological factors over more resource demanding species. For this reason, coniferous species have been chosen for the reforestation module in Espadán. On a further note, *Quercus ilex,* despite its low representation in the area (6%), as can be seen on the Table 14, could be considered as potential species for reforestation in marginal lands, due to its endurance to both high and low temperatures and arid conditions during summer.

Table 14. Area distribution for the main species in Sierra de Espadán, Castellón according to the MFE50.

Species	Area ha	Area %	Frequency
Ceratonia siliqua	0.70	0.01%	1
Pinus halepensis	6,786.63	70.04%	156
Pinus nigra	2.45	0.03%	1
Pinus pinaster	974.26	10.05%	34
Populus nigra	36.55	0.38%	4
Quercus faginea	75.75	0.78%	4
Quercus ilex	621.57	6.41%	24
Quercus suber	1,192.37	12.30%	27
Total	9,690.28	100.00%	251

Teruel: Nogueruelas

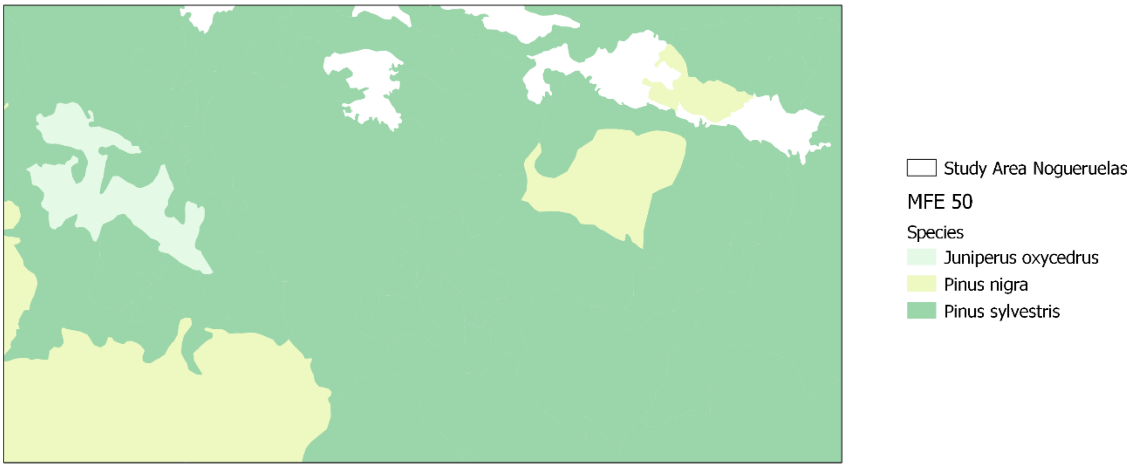


Figure 10. Species distribution in Nogueruelas, Teruel. Source MFE50.

As in other test sites in Spain, Nogueruela's test site is mainly populated by coniferous species (Table 15). In this area, the species composition is led by *Pinus sylvestris* and followed by *Pinus nigra*. Additionally, scarce formations of *Juniperus oxycedrus* appear in the study area. Next, the species abundance and area distribution are summarized:

Table 15. Area distribution for the main species in Nogueruelas, Teruel according to the MFE50.

Species	Area hectares	Area %	Frequency
Juniperus oxycedrus	71.91	3.21%	1
Pinus nigra	331.97	14.83%	10

Pinus sylvestris	1835.29	81.96%	28
Total	**2,239.17**	**100.00%**	**39**

The species selected for the reforestation modules were *Pinus sylvestris* and *Pinus nigra* as they were the most abundant.

<u>Degree of marginality in the pilot sites</u>

To estimate the area to be reforested, it is necessary to know the area of the marginal lands present in each of the eight pilot sites: Staszów (Poland), Thessaloniki (Greece), Rhodope-Komotini (Greece), Welzow (Germany), Nochten (Germany), Nogueruelas (Spain), Espadan (Spain) and Soria (Spain). For this purpose, in Task 2.3 the methodology for the identification of marginal lands and their corresponding degree of marginality ("Marginal lands with high plantation suitability", "Marginal lands with low plantation suitability", "Potentially unsuitable lands") was elaborated for Europe. As a result of this task, a European layer of marginal lands was obtained, and the degree of marginality was calculated following three methodological approaches. Following up, the area occupied by each marginality category "Marginal lands with high plantation suitability", "Marginal lands with low plantation suitability", "Potentially unsuitable lands" for each method on each pilot site and the percentage that marginal lands represent over the total area of each pilot site was calculated (Table 16).

According to the Deliverable of Task 2.3 a classification of the MLs is provided in three groups:

1. MLs with high plantation suitability
2. MLs with low plantation suitability
3. Potentially unsuitable lands

Table 16. Hectares and percentage of total area for each of the marginal land categories according to marginality ("Marginal Lands with high plantation suitability", "Marginal Lands with low plantation suitability", and "Potentially unsuitable lands") for each pilot site

		Poland (Staszów)		Greece (Thessaloniki)		Greece (Komotini)		Germany (Welzow)		Germany (Nochten)		Spain (NoguerueIas)		Spain (Espadán)		Spain (Soria)	
Method	**Type**	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
A	***MLs with high plantation suitability***	0.0	0.0	2,596.9	26.9	568.9	7.1	27.1	0.1	6.6	0.0	0.0	0.0	0.0	0.0	3,611.5	6.3
	MLs with low plantation suitability	19.6	0.0	1,887.3	19.5	1,809.6	22.6	1,554.8	7.0	2,023.3	1.9	12.7	0.5	341.8	3.0	19,194.2	33.3
	Potentially unsuitable lands	4,076.4	8.5	147.3	1.5	435.0	5.4	4,951.2	22.3	19,090.6	18.3	14.6	0.6	282.0	2.4	2,913.7	5.0
	Total MLs	4,096.0	8.5	4,631.5	47.9	2,813.5	35.2	6,533.0	29.4	21,120.5	20.3	27.3	1.2	623.9	5.4	25,719.3	44.6
B	***MLs with high plantation suitability***	17.8	0.0	4,377.4	45.3	2,024.8	25.3	1,095.4	4.9	1,255.5	1.2	0.3	0.0	103.0	0.9	20,367.3	35.3
	MLs with low plantation suitability	3,487.6	7.3	243.6	2.5	788.7	9.9	5,437.6	24.5	17,891.5	17.2	21.0	0.9	272.1	2.4	5,082.2	8.8
	Potentially unsuitable lands	590.6	1.2	10.5	0.1	0.0	0.0	0.0	0.0	1,973.5	1.9	6.0	0.3	248.7	2.2	269.9	0.5
	Total MLs	4,096.0	8.5	4,631.5	47.9	2,813.5	35.2	6,533.0	29.4	21,120.5	20.3	27.3	1.2	623.9	5.4	25,719.3	44.6
C	***MLs with high plantation suitability***	18.9	0.0	4,391.9	45.4	2,241.5	28.0	1,581.1	7.1	1,933.4	1.9	12.7	0.5	341.2	3.0	22,587.9	39.1
	MLs with low plantation suitability	1,682.5	3.5	161.5	1.7	572.0	7.2	4,952.0	22.3	14,043.5	13.5	8.3	0.4	33.7	0.3	2,751.0	4.8
	Potentially unsuitable lands	2,394.6	5.0	78.1	0.8	0.0	0.0	0.0	0.0	5,143.6	4.9	6.4	0.3	249.0	2.2	380.5	0.7
	Total MLs	4,096.0	8.5	4,631.5	47.9	2,813.5	35.2	6,533.0	29.4	21,120.5	20.3	27.3	1.2	623.9	5.4	25,719.3	44.6

3.1.2 Identification of the suitable species for afforestation in the pilot sites

3.1.2.1 Germany

Concerning the present deliverable reforestation plantings with *Pinus sylvestris* and *Picea abies* was applied in the Germany pilot sties, as concluded in deliverable 4.2. Therefore, any calculations of carbon in the wood products will be limited to these species.

As explained in other sections, these two species were selected because of the high relevance and presence on the area where the pilot sites are located, being considered as the dominant species on that area. Based on the results of task 4.2 a mix of the two species is the better option to improve the biodiversity and carbon stocked. Besides that, following scientific literature about the silviculture on that German area, 2 interventions will be conducted before the final cut, and all this process will generate wood that will be destinated to products.

For the present deliverable a standard division for wood products, based mainly on thresholds for the diameters of the trees was considered on the interventions activities, without taking into account the market demand, but it's important to take into account that this play an important role on the wood product process. Based on that, three main wood products will be derived from the pilot sites and this species, which will be the pulp/fiberboard, sawn wood and wood panels.

3.1.2.2 Greece

For the needs of the present deliverable, it will be foreseen to apply reforestation plantings with hardwood *Quercus frainetto* and softwood species *Pinus brutia* & *Pinus halepensis* in the Greek pilot sites, as concluded in deliverable 4.2. Therefore, any calculations of carbon in the wood products will be limited to these species.

3.1.2.3 Poland

The species of higher relevance in Poland sites was shown on deliverable 4.2, and will be the ones used on the present deliverable, being the *Pinus sylvestris* and *Quercus spp.* The oak species was highly used as natural or seminatural reforestation years ago, and in nowadays there's a highly increase of the presence and natural regeneration of pine on the Poland areas, being one of the most common species in all country (Banach J, Skrzyszewska K, SkrzyszewskiJ (2017).

A mix of the two species will be implemented on the pilot area, with the purpose to increase the biodiversity of the area. Following scientific literature about the silviculture on that Poland area, 2 interventions before the final cut will be conducted, and all this process will generate wood that will be destinated to products.

As in the other countries, for the Poland site a standard division for wood products, based mainly on thresholds for the diameters of the trees on the interventions activities was considered, without taking into account the market demand, but it's important to take into account that this play an important role on the wood product process. For example, in the case of Poland, the most present and demanded product is the roundwood, but this product will not be considered on this deliverable. Just three main wood products will be derived from the pilot sites and this species, which will be the pulp/fiberboard, sawn wood and wood panels.

3.1.2.4 Spain

For the needs of the reforestations in Spain, it will be foreseen to apply plantings with *Pinus sylvestris* & *Pinus nigra* in the pilot sites of Soria and Nogueruelas and with *Pinus halepensis* & *Pinus pinaster* for Espadán pilot site as concluded in deliverable 4.2. Therefore, any calculations of carbon in the wood products will be limited to these species.

3.2 Estimation of future biomass.

3.2.1 Reforestation modules, designing the future forests

Reforestation modules were designed to assess the potential of MLs for biomass production and HWPs. The modules include scenarios based on site index and different species composition depending on the pilot site. Moreover, the proposed silvicultural treatments vary across species based on age and SI. The variables taken into account for the development of the reforestation modules are described in detail for each country.

3.2.1.1 Definition of the variables of the reforestation module

For the needs of the reforestation plan the following have been taken into account:

Site quality index (SI) refers to the inherent ability of a forest to produce biomass; that is, to grow trees. Since marginal lands are of low productivity, it was assumed that forest productivity will refer to the lowest site quality class.

3.2.1.1.1 Germany

In the whole German territory there are different forest species, all of them are currently recorded and are monitored by the National Inventory, which is a legal mandate registered in the German Forest Law in Article 41a. The German forests are inventoried every ten years, starting from the period of 1986-1988. The last one that was carried out was in 2011/2012, being the third. Based on that, the species that will be used in the pilot sites were selected. The criteria used for this selection were based on the species that are more present in the pilot areas. In the area of Brandenburg and Sachsen the dominant species are the *Pinus sylvestris* and the *Picea abies* thus they were selected to be used on the reforestation module.

In the pilot sites, the planting patterns will be based on one mix of the two species, with the planting patterns no larger than 1 x 1.4 m. The trees should be planted in a way to better provide growing space and light, which will help the development of the trees that will be used for different wood products in the future on the final cutting and also in the thinning interventions. As shown on deliverable 4.2 the *Picea abie*s can stock more carbon than *Pinus sylvestris*. A model where 60% of the area will be planted *Picea abies* and 40% with *Pinus sylvestris* will be applied.

3.2.1.1.2 Greece

Forest plantations in Greece are mostly undermanaged since their main purpose of existence is either regulatory (protection from floods and soil erosion) or aesthetic (recreation sites). In Greece, plantations of oak forests (*Quercus frainetto*) in the ***MAIL*** pilot sites will not be subject to any interventions nor final clear cuttings for wood extraction, while Pinus plantations may be subject to one thinning intervention.

Regarding the planting patterns, these may be adapted according to the purpose of the plantation but also considering the marginality conditions. Trees should be established in a pattern that optimizes growing space and light penetration for high-quality wood. In general, the selection of the planting pattern entails considering (a) dense planting to achieve fast and successful restoration but also (b) large enough so as to keep expenses of the planting procedure moderate.

Planting patterns for *Pinus brutia* and *Pinus halepensis* should not be larger than 2 x 2 m. Trees could be established in a moderate pattern of planting, meaning that the pattern should be established considering the close-to-planting conditions of the landscape.

Oak plantations could be established in a natural pattern (not sticking to equal distances among seedlings) and with wide spacing (e.g. 2 x 2 m) as they would not be targeted for final clear cutting and wood harvesting. 2500 trees/ha is proposed as initial plantation density for plantations of both conifers and broadleaves.

3.2.1.1.3 Poland

Based on the information of the forest inventory from the Polish Forest Data Bank is possible to notice the high diversity of species but as in the other cases, some of these species are the predominant. In the case of the Poland test sites the species with more relevance due to the existence on the area are the *Pinus sylvestris* and *Quercus spp.*

Taking this into account a mixed of the two species thinking to enhance the biodiversity and carbon stocked scenario will be planted. Approximately 70% *Quercus spp.* and 30% *Pinus sylvestris* will be planted, which will also provide some resilience in the landscape against climate risks and pests.

A plantation with a 1 x 0.8 – 1m will be carried out. The trees should be planted in a way to better provide growing space and light, which will help the development of the trees that will be used for different wood products in the future on the final cutting and also in the thinning interventions.

3.2.1.1.4 Spain

Spanish forest plantation culture is mostly oriented towards forest management for wood production. Therefore, it was assumed that one (1) silvicultural intervention (thinning) will be carried out before final clear cutting in the Spanish pilot sites.

Typically, 1600 trees/ha is proposed as initial plantation density in Castilla y León, while the first entry of the yield tables for the reforestation manual start at 1500, based on the assumption that around a 10% can die after planting. For Spain a common plantation pattern would span between 1,5 x 1,5 meters to 2 x 2 meters. Planting patterns should keep equal distances among seedlings as these will be purposed for wood harvesting for commercial reasons.

3.2.2 Review of existing growth models, yield tables

Yield models for a given species try to describe the evolution of the main stand variables in relation to age, by means of various functions. Production models of variable silviculture are obtained if the stand has been thinned, and there is experimental record of its response to different intensities of thinning. These models describe the evolution of variables for the main stand before and after the thinning, the timber removed and the total volume. In the absence of solid experience in the response of the species to different thinning regimes, it is necessary to accept the risk of proposing untested models of variable silviculture, which, despite their being based on indices of proven efficiency for other species, may lead to errors, especially when there is little experience in the construction of production models, and little knowledge of the silviculture of this species.

For the needs of the present deliverable, yield tables for the forest tree species to be used for the reforestation modules at each country pilot site were reviewed from the literature. It has been assessed which models are the most suitable to study the evolution of the non-forested MLs into forested MLs for each country.

Taking into consideration the results of deliverable 4.2 a methodology is contemplated that provides a mixture of species that maximizes carbon sequestration for a given pair of species, for a year, in a pilot site.

First, marginality classes are related to yield through site index (SI). Considering that by definition, marginal lands have low yields, the yield tables selected corresponded to the lowest SI available for the marginality class 2 and the second lowest for marginality class 1. Then, for each species and SI; carbon values were calculated by ha before and after a silvicultural treatment. Therefore, for a given year and species, we have 4 Carbon estimation values:

1. Marginality class 1 (second lowest SI) and with silvicultural intervention (thinnings)
2. Marginality class 1 (second lowest SI) and without silvicultural intervention (thinnings)
3. Marginality class 2 (lowest SI) and with silvicultural intervention (thinnings)
4. Marginality class 2 (lowest SI) and without silvicultural intervention (thinnings)

3.2.2.1 Germany

For the Germany pilot sites, two forest species will be used:

- *Picea abies*
- *Pinus sylvestris*

These two species were selected based on the analysis of the national forest inventory in the German forest areas. The most present species in Brandenburg region and Sachsen region were analyzed, which are the areas where the Marginal pilot sites are located.

The most dominant species in the Brandenburg area, where the Welzow pilot site was located, is the *Pinus sylvestris* and in the Sachsen area, the most dominant species is the *Picea abies.* The yield table of Lembcke et al, 1975 was used with respect to the *Pinus sylvestris*, once well representing the growing of this species in the pilot area. For the *Picea abies,* the tables of Schober, 1975 were used. In the two pilot sites, two silvicultural treatments will be considered, one at 30/35 years and another one in 50 years, and a final cut at the 100 years.

Different scenarios will be considered as in the case shown in deliverable 4.2. Basically, considering the two lower quality sites (18, 20) for *Pinus sylvestris,* and with a case of low thinning intensity. In the scenario of *Picea abies,* will be considered also the lowest quality sites (scenario IV and V of production), with a case of medium thinning intensity.

Based on that we have the following scenarios:

Marginal Land 1: The quality site 20 for the *Pinus sylvestris* and scenario IV of *Picea abies.*

Marginal Land 2: 18 of quality site for the *Pinus sylvestris* and scenario V to *Picea abies.*

3.2.2.2 Greece

For the Greek pilot sites, the forest species that were used for both sites are

- *Pinus halepensis* & *Pinus brutia*

- *Quercus frainetto*

Given the lack of information on *Pinus halepensis* yield estimations for Greece, Spanish yield tables were used Montero et al., 2001). Despite being from a different geographical area, both ecological distributions hold similar environmental characteristics. Therefore, the yield values proposed by Montero were considered suitable for the Greek pilot sites.

Also, given the lack of information on *Pinus brutia* yield table data, *Pinus halepensis* & *Pinus brutia* will be treated as a group because they are adapted at the same environmental conditions; they grow at low altitudes close to the sea. Due to the fact that data on yield tables were found only for *Pinus halepensis (*Montero, 2000) and not for *Pinus brutia* it will be foreseen to use *Pinus halepensis* yield table data for both species. *Pinus halepensis* yield table data were cross-checked with field data of *Pinus brutia* in Greece and it has been concluded that *Pinus halepensis* data describe the Greek context very well.

For the *Quercus sp.,* Kossenakis yield tables for coppice stands of *Quercus frainetto*, were used (Kossenakis, 1939), as these are applied at regional and national level.

The periods of checking the production of the yields projection will be defined at:

(a) 30, 50 and one year before the final clear-cut which will be on 90 years for Pinus species

(b) 30, 45 and one year before clear cut which will be on 90 years for Quercus species

Site indexes selected for *Pinus halepensis* and *Pinus brutia* were equivalent to 14 for marginal lands of type 1, and production class Va was selected for *Quercus sp.* On the other hand, the yield values for the site index equal to 11 were used for the marginal lands type 2 only for *Pinus halepensis* and *Pinus brutia*. (Table 17)

Table 17. Marginality classes per reforestation species for the Greek pilot sites

Marginality classes	*Pinus halepensis & Pinus brutia*	*Quercus sp.*
Marginality class 1 (second lowest SI)	14	Va
Marginality class 2 (lowest SI)	11	-

The yield values for *Quercus frainetto* are presented in Table 18, where *SI* refers to the stand quality, *year* represents the stand age, *N* is the number of trees per hectare, *Hm* is the mean stand height in meters, *G* is the basal area in m^2 per hectare, *DBH* is the diameter at breast height in cm, *Vol+bark* is the stand tree wood and bark volume in m^3 per hectare, *Vol is the* stand tree wood volume in m^3 per hectare and *Dry weight* is the dry biomass of the trunk volume. The table for *Pinus halepensis* yield data is shown later in the document for the Spanish pilot cases.

Table 18. *Quercus* species yield table. Class quality Va (second lowest production).

SI	Age	N	Hm	G	DBH	Vol+ bark	Vol	Dry weight
	year	trees/ ha	m	m^2/ ha	cm	m^3/ ha	m^3/ ha	kg/ ha
Va	10	9,100	3.2	6.4	3	16	10.46	11,840
Va	12	8,820	3.7	6.88	3.1	19.6	12.84	14,504
Va	14	8,540	4.2	7.35	3.3	23.4	15.42	17,316
Va	15	8,400	4.4	7.72	3.4	25.6	16.92	18,944
Va	16	8,262	4.6	8.1	3.5	27.8	18.42	20,572
Va	18	7,980	5	8.78	3.7	32.4	21.59	23,976
Va	20	7,700	5.4	9.38	3.9	36.6	24.53	27,084
Va	22	7,380	5.7	9.9	4.1	40.6	27.39	30,044
Va	24	7,060	6	10.3	4.3	44.2	30.04	32,708

Va	25	6,900	6.2	10.4	4.4	45.8	31.3	33,892
Va	26	6,700	6.3	10.6	4.5	47.35	32.48	35,039
Va	28	6,300	6.6	10.8	4.7	50.4	34.78	37,296
Va	30	5,900	6.9	11	4.9	53.2	36.96	39,368
Va	32	5,420	7.1	11.2	5.1	55.8	39	41,292
Va	34	4,940	7.4	11.3	5.4	58	40.87	42,920
Va	35	4,700	7.5	11.4	5.5	59.1	41.76	43,734
Va	36	4,620	7.6	11.5	5.6	60.1	42.58	44,474
Va	38	4,460	7.8	11.5	5.7	62.1	44.11	45,954
Va	40	4,300	8	11.6	5.8	63.9	45.51	47,286
Va	42	4,300	8.2	16.2	5.9	65.7	46.82	48,618
Va	44	4,300	8.4	16.3	5.9	67	47.85	49,580
Va	45	4,300	8.5	16.4	5.9	67.7	48.35	50,098

3.2.2.3 Poland

For the Poland pilot sites the species that were used are the *Pinus sylvestris,* and the *Quercus spp.* The two species are the most present ones on the pilot site area based on the Polish Forest Data Bank.

These two species were selected to be used as reforestation species on the pilot site in Poland. To have a good overview and estimate of the future scenario, some yield tables from Szymkiewicz, 2001 were used, which contain information about the two species in different classes of quality site and treatments. As in the other cases, two intermediate thinning will be carried out at 30 and 50 years, and a final cut at 100 years. For the Marginal Land scenario, the weak treatments were considered, and the 2 worst classes have been selected. In that way two Marginal Lands scenarios were build, as can be seen on the deliverable 4.2

Marginal Land 1: *Pinus sylvestris* Class IV + *Quercus spp*. Class III

Marginal Land 2: *Pinus sylvestris* Class V + *Quercus spp.* Class IV

Besides that, following what was presented on deliverable 4.2, the proportion of the species on the plantation will be of 70% *Quercus spp.* and 30% *Pinus sylvestris.*

3.2.2.4 Spain

For the Spanish pilot sites, the forest species that will be used are:

- *Pinus sylvestris* & *Pinus nigra* for the pilot sites of Soria and Nogueruelas

- *Pinus halepensis* & *Pinus pinaster* for the pilot site of Espadan

The periods of checking the production of the yield's projection will be defined at 30, 50 and one year before the final clear-cut (which is at 90 years for *Pinus nigra*, 80 years for *Pinus pinaster*, 120 years for *Pinus halepensis* and 120 years for *Pinus sylvestris*).

The reforestation guide for Castilla y Leon (del Río et al., 2006) proposes reforestation and management plans for 3 coniferous species in Castilla y León (*Pinus pinaster, P. nigra* and *P. sylvestris*). The management plans consist of applying thinning to maintain the stand density within a defined threshold of observed density. Two site index values were selected for each species. Specifically, the most restrictive site index values were chosen (SI = 15 and SI = 12). Then, for each quality site, the yield was estimated for a management plan that considered silvicultural treatments every 10 years (thinning).

Table 19. Marginality classes per reforestation species for the Spanish pilot sites

Marginality classes	*Pinus sylvestris*	*Pinus nigra*	*Pinus pinaster*	*Pinus halepensis*
Marginality class 1 (second lowest SI)	15	15	15	14
Marginality class 2 (lowest SI)	12	12	12	11

The tables extracted from the reforestation guide are shown in Table 20, Table 21, Table 22 and

Table 23, where *quality* is the stand quality, *Age* represents the stand age, H_o is the dominant stand height in meters, *N* is the number of trees per hectare, *Hm* is the stand mean height, *Dg* is the mean square diameter in cm, *G* is the basal area in m^2 per hectare and *V* is the tree wood volume in m^3 per hectare.

Table 20. *Pinus pinaster* yield table with lowest class (12) and second-lowest class quality production (15).

Species	Quality	Age	Before thinning					Thinning			After thinning			
			Ho	N	Dg	G	V	N	Dg	V	N	Dg	G	V
		years	*m*	*trees/ha*	*cm*	*m²/ha*	*m³/ha*	*trees/ha*	*cm*	*m³/ha*	*trees/ha*	*cm*	*m²/ha*	*m³/ha*
P. pinaster	12	40	10.4	1,500	13	21.1	92.8	575	12	29.4	925	14	14.6	63.4
P. pinaster	12	50	12	925	19	26.9	136	375	16.7	42.4	550	20.8	18.6	93.2
P. pinaster	12	65	13.6	550	27	31.2	178	150	24.2	40.1	400	27.8	24.3	138

P. pinaster	12	80	14.6	400	33	33.1	202	-	-	-	-	-	-	-
P. pinaster	15	35	11.7	1,500	14	24.2	119	575	12.9	37.8	925	15.2	16.7	81.6
P. pinaster	15	45	14.1	925	21	31.2	183	375	18.0	57.2	550	22.4	21.6	126
P. pinaster	15	60	16.5	550	29	36.1	246	200	26.0	73.8	350	30.4	25.5	172
P. pinaster	15	75	17.9	350	37	37.9	280	-	-	-	-	-	-	-

Table 21. *Pinus nigra* yield table with lowest class (12) and second-lowest class quality production (15).

Species	Quality	Age	Before thinning					Thinning			After thinning			
			Ho	N	Dg	G	V	N	Dg	V	N	Dg	G	V
		years	*m*	*trees/ ha*	*cm*	*m²/ ha*	*m³/ ha*	*trees/ ha*	*cm*	*m³/ ha*	*trees/ ha*	*cm*	*m²/ ha*	*m³/ ha*
P. nigra	12	45	10.8	1,500	17	33.3	161	500	15	42.8	1,000	18	24.5	118
P. nigra	12	60	14.3	1,000	22	37.9	234	350	19.1	62.3	650	23.3	27.8	171
P. nigra	12	75	17.2	650	27	36.2	263	225	22.6	66.3	425	28.5	27.2	197
P. nigra	12	85	18.9	425	30	29.8	234	-	-	-	-	-	-	-
P. nigra	15	40	12.2	1,500	19	40.8	220	550	16.6	64.3	950	19.7	29	156
P. nigra	15	55	16.3	950	25	45.3	313	350	21.4	88	600	26.3	32.6	225
P. nigra	15	70	19.5	600	30	41.8	339	200	25.3	82.1	400	31.8	31.7	257
P. nigra	15	80	21.3	400	33	34.4	300	-	-	-	-	-	-	-

Table 22.*Pinus sylvestris* yield table with lowest class (12) and second-lowest class quality production (15).

Specie	Quality	Age	Before thinning					Thinning			After thinning			
			Ho	N	Dg	G	V	N	Dg	V	N	Dg	G	V
		years	*m*	*trees/ ha*	*cm*	*m²/ ha*	*m³ /ha*	*trees/ ha*	*cm*	*m³/ ha*	*trees/ ha*	*cm*	*m²/ ha*	*m³/ ha*
P. sylvestris	12	40	9.4	1,500	15	26.8	115	500	13.4	30.9	1000	15.9	19.7	83.7
P. sylvestris	12	55	13.2	1,000	20	30.1	176	375	16.6	48.6	625	21.1	21.9	127
P. sylvestris	12	70	13.9	625	25	29.9	183	175	22.2	42.3	450	25.6	23.2	141
P. sylvestris	12	110	15.9	450	31	34.8	241	-	-	-	-	-	-	-
P. sylvestris	15	35	10.4	1,500	16	29.1	137	550	14.0	40.4	950	16.6	20.6	96.1
P. sylvestris	15	50	15	950	21	32.8	215	375	17.8	62.4	575	22.8	23.4	152
P. sylvestris	15	65	16.9	575	27	32.2	235	175	24.0	59.1	400	27.8	24.3	176
P. sylvestris	15	110	19.9	400	34	37.2	315	-	-	-	-	-	-	-

Montero's yield table for *Pinus halepensis* (Montero et al., 2001) is built using information from 72 forest plots distributed within the natural distribution of *Pinus halepensis* and representing a wide range of site qualities. The plots were distributed throughout eastern and central easter Span, in the provinces of Albacete, Castellón, Jaén, Murcia, Teruel, Valencia, and Zaragoza. The document also provides a classification of the yield using as quality indicator the Richard's site index (Richards, 1959). In addition, several silvicultural regimes are proposed which determine the final yield output. The SI selected for *Pinus halepensis* were 11 and 14.

Table 23 shows the yield table of *Pinus halepensis*.

Table 23. *Pinus halepensis* yield table with lowest class (11) and second-lowest class quality production (14).

Species	Quality	Age	Before thinning					Thinning				After thinning			
			Ho	N	Dg	G	V	N	Dg	G	V	N	Dg	G	V
		years	*m*	*trees/ ha*	*cm*	*m²/ ha*	*m³/ ha*	*trees/ ha*	*cm*	*m²/ ha*	*m³/ ha*	*trees/ ha*	*cm*	*m²/ ha*	*m³/ ha*
P. halepensis	11	20	4.5	2,103	5.9	5.7	12.9	65	2.5	0	0.1	2,038	6	5.7	13
P. halepensis	11	30	6.2	2,038	8	10.1	30.2	86	3	0	0.3	1,952	8.1	10.1	30.1
P. halepensis	11	40	7.5	1,952	9.8	14.6	51.2	647	4	0.8	3.6	1,305	11.6	13.8	47.1
P. halepensis	11	50	8.7	1,305	13	17.1	65.8	72	6.1	0.2	4.5	1,233	13.2	16.9	64.8
P. halepensis	11	60	9.6	1,233	14	19.9	82.7	227	7.7	1.1	9.3	1,005	15.4	18.8	77.5
P. halepensis	11	70	10.4	1,005	16	21.1	92.5	143	9	0.9	13.7	862	17.3	20.2	87.8
P. halepensis	11	80	11	862	18	21.9	100	96	10.2	0.8	17.6	766	18.8	21.2	96.1
P. halepensis	11	90	11.5	766	19	22.6	107	67	11.1	0.6	21	699	20	21.9	102.9
P. halepensis	11	100	11.9	699	21	23	112	49	11.8	0.5	23.8	650	21	22.5	108.5
P. halepensis	11	110	12.3	650	21	23.4	116	37	12.4	0.4	26.2	613	21.8	23	113
P. halepensis	11	120	12.6	613	22	23.7	119	–	–	–	–	–	–	–	–
P. halepensis	14	20	5.7	1,586	8.5	9	24.7	105	3	0.1	0.2	1,481	8.8	9.1	24.7
P. halepensis	14	30	7.8	1,481	11	15	53.3	139	4.7	0.2	1.2	1,342	11.8	14.7	52.1
P. halepensis	14	40	9.6	1,342	14	20.3	85	336	7.6	1.5	8.2	1,006	15.4	18.8	77.4
P. halepensis	14	50	11	1,006	17	23.2	107	29	9.9	0.2	9.3	977	17.3	23	105.9
P. halepensis	14	60	12.2	977	19	26.8	135	180	11.7	1.9	19.7	797	19.9	24.9	123.6
P. halepensis	14	70	13.2	797	21	27.9	147	113	13.3	1.6	28.7	684	22.1	26.3	137.9
P. halepensis	14	80	14	684	23	28.6	157	76	14.7	1.3	36.3	608	23.9	27.3	149.5
P. halepensis	14	90	14.7	608	25	29.1	166	53	15.8	1	42.6	554	25.4	28.1	158.9
P. halepensis	14	100	15.2	554	26	29.5	172	39	16.7	0.9	47.9	515	26.6	28.6	166.5
P. halepensis	14	110	15.7	515	27	29.8	177	29	17.4	0.7	52.4	486	27.6	29.1	172.8
P. halepensis	14	120	16	486	28	30	182	–	–	–	–	–	–	–	234

3.2.3 Thinning and intermediate treatments

The implementation of intermediate treatments is a strategy widely used on the forests that can also help the better development of specific species. In the present study there will be some treatments but it is important to note that because of the lack of specific information about them on the yield tables the estimations can be interfered with on the final result, and will also present some different values from the tables and carbon presented on the deliverable 4.2.

3.2.3.1 Germany

In the pilot sites considering the case Marginal Land 1, the *Pinus sylvestris* in a mix with *Picea abies* will be planted with a distance of 1 x 1.4m, with this scheme almost 7,200 trees/ha will be obtained. Two treatments will be conducted, one thinning at 30/35 years and one at 50 years. The thinning will include almost 1,450 trees/ha at 30 years and 3,300 trees/ha at 50 years. At the end, based on the literature (Spathelf, P., and Ammer, C. 2015) and because of the available data of the yield tables, thinking on a more accurate estimation, the final cut will occur at 100 years. The first thinning will be mainly in the trees below 5 cm of DBH for *Pinus sylvestris* and below 5-5,5 cm of DBH for *Picea abies*. For the second thinning treatment, at 50 year the 10 cm DBH for *Pinus sylvestris* and for *Picea abies*. All these trees will be used for wood products based on their diameters.

Based on the thinning activities and the diameter of the trees, in the case of the *Pinus sylvestris,* a volume of 5.2 m³/ha at 30 years, 21.6 m³/ha at 50 years, and 172.0 m³/ha at the final cut will be obtained. In the case of the *Picea abies,* a volume of 2.83 m³/ha at 30 years, 9.99 m³/ha at 50 years, and 281.15 m³/ha at the final cut will be obtained.

In the pilot sites considering the case Marginal Land 2 the *Pinus sylvestris* in a mix with *Picea abies*, will be planted with a distance of 1 x 1.2 m, with this scheme almost 8,250 trees/ha will be obtained. Two treatments will be conducted, one thinning at 30/35 years and one at 50 years. The thinning will include almost 1,650 trees/ha at 30 years and 3500/ha at 50 years. The first thinning will be mainly in the trees below 5 cm of DBH for *Pinus sylvestris* and below 5-5,5 cm of DBH for *Picea abies*. For the second thinning treatment, at 50 year the 10 cm DBH for *Pinus sylvestris* and for *Picea abies*. All these trees will be used for wood products based on their diameters.

Based on the thinning activities and the diameter of the trees, in the case of the *Pinus sylvestris,* a volume of 4.4 m³/ha at 30 years, 18.8 m³/ha at 50 years, and 149.2 m³/ha at the final cut will be obtained. In the case of the *Picea abies,* a volume of 2.046 m³/ha at 30 years, 5.706 m³/ha at 50 years, and 191.85 m³/ha at the final cut will be obtained as can be seen on the Table 24 and Table 25.

Table 24. Marginal Land I Germany

Treatment	**Vol (m³/ha) *Pinus sylvestris***	**Vol (m³/ha) *Picea abies***
Thinning 30 Y	5.2	2.83
Thinning 50 Y	21.6	23.13
Final Cut	172	281.15

Table 25. Marginal Land II Germany

Treatment	**Vol (m³/ha) *Pinus sylvestris***	**Vol (m³/ha) *Picea abies***
Thinning 30 Y	4.4	2.04
Thinning 50 Y	18.8	12.0
Final Cut	149.2	191.85

For the estimation of the volume in *Pinus sylvestris* the yield table considering just two specific dates for thinning and the final year as harvesting as total clear cut was used, in other hand, for the *Picea abies,* once there’s no information about volume thinned, a simple model was developed based on the available data related to the diameter and the volume, to establish an allometric relation between this variables by using a power type equation and processed on python, and as a result the model gave a value of an estimated volume of our thinning management based on the diameter threshold established before.

3.2.3.2 Greece

<u>*Pinus halepensis & Pinus brutia*</u>

(a) will be subject to one silvicultural thinning in Greece

(b) will be planted at sites of the lowest SI, as they are less demanding species (SI=11).

<u>*Quercus frainetto*</u>

(a) will not be subject to silvicultural thinning

(b) will be planted at sites of second lowest SI (14=Va)

Therefore, we have the following scenarios of reforestation plantings according to marginality classes that include different treatments and mixture of species (Table 26).

Table 26. Marginality class scenarios that correspond to each reforestation species in the Greek pilot sites, thinning scenarios and mixture proposed for each scenario.

Forest species		Forest species	Mixture	Silvicultural treatments
Marginality class 1 (second lowest SI)	14	*Pinus halepensis & Pinus brutia*	50%	No thinnings
				One thinning on 30 years
	Va	*Quercus* sp.	50%	No thinnings
Marginality class 2 (lowest SI)	11	*Pinus halepensis & Pinus brutia*	-	No thinnings
				One thinning on 30 years

For the biomass and carbon estimation for *Pinus halepensis* & *Quercus frainetto* the calculations of the aboveground and belowground components and total tree were used from Deliverable 4.2. These estimations are based on the yield tables of Montero (2005) and Kossenakis (1939) respectively, but now they are contrasted against the number of trees (N) that is calculated according to the planting pattern of the reforestation module in the pilot sites.

Table 27. Progress of the number of trees per ha (N) throughout the production monitoring period for each thinning scenario in the Greek pilot sites.

			Marginality class 1 (second lowest SI)		**Marginality class 2** (lowest SI)
Scenarios		**Species**	***Pinus halepensis & Pinus brutia***	***Quercus* sp.**	***Pinus halepensis & Pinus brutia***
		Initial planting (N)	**2,500**	**2,500**	**2,250**
No thinning scenario	**1st year**	**Loss due to unsuccessful planting (40%)**	1,250	2,250	1,500
	45 years	**Loss due to natural selection (10%)**		2,025	
	50 years	**Loss due to natural selection (20%)**	1,000		1,200
	90 years	**Loss due to natural selection (20%)**	800	1,822	960
Thinning scenario	**1st year**	**Loss due to unsuccessful planting (40%)**	1,250	2,250	1,500
	30 years	**Loss due to thinning (10%)**	1,125		1,350
	45 years	**Loss due to natural selection (10%)**		2,025	
	50 years	**Loss due to natural selection (20%)**	900		1,080
	90 years	**Loss due to natural selection (20%)**	720	1,822	864

3.2.3.3 Poland

In the pilot sites considering the case Marginal Land 1, the *Pinus sylvestris* in a mix with *Quercus spp* will be planted with a distance of 1 x 1.m, with this scheme almost 10000 trees/ha will be obtained. Two treatments will be conducted, one thinning at 30/35 years and one at 50 years. The thinning will include almost 5500 trees/ha at 30 years and 3000 trees/ha at 50 years. At the end, based on the available data of the yield tables, thinking on a more accurate estimation, the final cut will occur at 100 years. It is important to consider that the different rotation periods can help the natural tree regeneration. The first thinning will be mainly in the trees below 5 cm of DBH for

Pinus sylvestris and *Quercus spp*. For the second thinning treatment, at 50 year the 10 cm DBH for *Pinus sylvestris* and also for *Quercus spp.* All these trees will be used for wood products based on their diameters. It is expected that the volume extracted from the forest would be higher related with the *Quercus spp.* since it is the species with the higher number of trees and the proportion of thinning will follow the proportion of plantation where 70% will be *Quercus spp* and 30% of the total thinned and harvested trees will be *Pinus sylvestris (Table 28).*

Based on the thinning activities and the diameter of the trees, on the ML1 scenario, in the case of the *Pinus sylvestris,* a volume of 10.48 m³/ha at 30 years, 42.72 m³/ha at 50 years, and 312.33 m³/ha at the final cut will be obtained. In the case of the *Quercus spp.,* a volume of 45.53 m³/ha at 30 years, 119.01 m³/ha at 50 years, and 941.56 m³/ha at the final cut will be obtained.

Considering the case Marginal Land 2, the *Pinus sylvestris* in a mix with *Quercus spp* will be planted with a distance of 0.9 x 0.9 m, with this scheme almost 14,500 trees/ha will be obtained. Two treatments will be conducted, one thinning at 30/35 years and at 50 years/ The thinning will include 7,100 trees/ha at 30 years and 5,000 trees/ha at 50 years. At the end, based on the available data of the yield tables, thinking on a more accurate estimation, the final cut will occur at 100 years. It is important to considered that the different rotation periods can help the natural tree regeneration. The first thinning will be mainly in the trees below 5 cm of DBH for *Pinus sylvestris* and below 3 cm of DBH for *Quercus spp* once the area has a slow growth. For the second thinning treatment, at 50 year the 9 cm DBH for *Pinus sylvestris* and below 8 cm of DBH for *Quercus spp.* All these trees will be used for wood products based on their diameters.

Based on the thinning activities and the diameter of the trees, in the case of the *Pinus sylvestris,* a volume of 12.98 m³/ha at 30 years, 42.82 m³/ha at 50 years, and 252.15 m³/ha at the final cut will be obtained. In the case of the *Quercus spp.,* a volume of 38.17 m³/ha at 30 years, 131.60 m³/ha at 50 years, and 812.99 m³/ha at the final cut will be obtained. The reason why the *Quercus spp* will have higher volume on the thinning is directly related with the number of trees per ha of this species (Table 29).

Table 28. Marginal Land I in Poland pilot area.

Treatment	Vol (m^3/ha) *Pinus sylvestris*	Vol (m^3/ha) *Quercus spp*
Thinning 30 Y	10.48	45.53
Thinning 50 Y	42.72	119.01
Final Cut	312.33	941.56

Table 29. Marginal Land II in Poland pilot area.

Treatment	Vol (m^3/ha) *Pinus sylvestris*	Vol (m^3/ha) *Quercus spp*
Thinning 30 Y	12.98	38.17
Thinning 50 Y	42.82	131.60
Final Cut	252.15	812.99

3.2.3.4 Spain

Pinus nigra & Pinus sylvestris

(a) will be subject to three silvicultural thinnings in Spain

(b) will be planted at sites with high and low plantation suitability (SI=12 and SI=15)

Pinus halepensis & Pinus pinaster

(a) will be subject to three silvicultural thinnings for *P. pinaster* and ten moderate thinnings for *P. halepensis*

(b) will be planted at sites of lowest and second lowest SI, as they are the less demanding species (SI=11 and SI=14).

As mentioned above, in overall three thinnings are performed in pine forests before the final logging in Spain. The ages vary depending on the species and site quality for *P. pinaster, P. nigra* and *P. sylvestris* as shown in Table 30.

Table 30. Thinning ages *for P. pinaster, P. nigra and P. sylvestris*, depending on site quality

Species	Quality 12			Quality 15		
	1st thinning	2nd thinning	3rd thinning	1st thinning	2nd thinning	3rd thinning
Pinus pinaster	40	50	65	35	45	60
Pinus nigra	40	50	65	40	55	70
Pinus sylvestris	40	55	70	35	50	65

In *Pinus halepensis* forests moderate thinnings are carried out every 10 years, starting from the age of 20 until the rotation age of 120, for site quality 11 and 14 (Table 31).

Table 31. Thinning ages for *P. halepensis* for site qualities 11 and 14

Species	Qualities 11 & 14									
	1st thin.	2nd thin.	3rd thin.	4th thin.	5th thin.	6th thin.	7th thin.	8th thin.	9th thin.	10th thin.
Pinus halepensis	20	30	40	50	60	70	80	90	100	110

Although monocultures maximize the carbon intake of MLs it is encouraged to apply a mixture to enhance biodiversity, resilience against disturbances such as forest fires, extreme weather events and pest, following the ratios below for each pilot site:

- in Soria, a mixture of *Pinus nigra* in 70-80 % and *Pinus sylvestris* in 20-30%,
- in Nogueruelas, a mixture of *Pinus nigra* in 70-80 % and *Pinus sylvestris* in 20-30%,
- in Espadan, a mixture of *Pinus pinaster* in 70-80 % and *Pinus halepensis* in 20-30%,

Detailed information on the number of trees (N) per species that is calculated according to the planting pattern of the reforestation module in the pilot sites are provided in Table 32, Table 33, Table 34 & Table 35.

Table 32. Progress of the number of trees per ha (N) throughout the checking of the production for *Pinus pinaster*.

Quality	State	Age (years)							
		35	40	45	50	60	65	75	80
12	Before thinning		1,500		925		550		400
	Thinning (N removed)		575		375		150		
	After thinning		925		550		400		

15	Before thinning	1,500		925		550		350	
	Thinning (N removed)	575		375		200			
	After thinning	925		550		350			

Table 33. Progress of the number of trees per ha (N) throughout the checking of the production for *Pinus nigra*.

Quality	State	Age (years)					
		40	50	55	65	70	80
12	Before thinning	1,500	1,000		650		425
	Thinning (N removed)	500	350		225		
	After thinning	1,000	650		425		
15	Before thinning	1,500		950		600	400
	Thinning (N removed)	550		350		200	
	After thinning	950		600		400	

Table 34. Progress of the number of trees per ha (N) throughout the checking of the production for *Pinus sylvestris.*

Quality	State	Age (years)						
		35	40	50	55	65	70	110
12	Before thinning		1,500		1,000		625	450
	Thinning (N removed)		500		375		175	
	After thinning		1,000		625		450	
15	Before thinning	1,500		950		575		400
	Thinning (N removed)	550		375		175		
	After thinning	950		575		400		

Table 35. Progress of the number of trees per ha (N) throughout the checking of the production for *Pinus halepensis*.

Quality	State	Age (years)										
		20	30	40	50	60	70	80	90	100	110	120
11	Before thinning	2,103	2,038	1,952	1,305	1,233	1,005	862	766	699	650	613
	Thinning (N removed)	65	86	647	72	227	143	96	67	49	37	-
	After thinning	2,038	1,952	1,305	1,233	1,006	862	766	699	650	613	-
14	Before thinning	1,586	1,481	1,342	1,006	977	797	684	608	554	515	486
	Thinning (N removed)	65	86	647	72	227	143	96	67	49	37	

	After thinning	1,521	1,395	695	934	750	654	588	541	505	478	-

3.2.4 Destination of the harvested wood from MLs plantings

Under the assumption that in the pilot sites of the ***MAIL*** project, site quality is of the lowest class the expected wood product categories of the roundwood harvest will have to be defined under both the demands of the wood industry market for each country as well as under the perspective of wood productivity from such lands.

3.2.4.1 Germany

Based on Table 1, showed in section 2.2, which has as reference the normative EN 1927, we can establish some thresholds that will guide the destination of the trees to wood products related with the *Pinus sylvestris* and *Picea abies* species:

- Diameter ≤ 6 cm will be destined to Fiberboard and Pulp.
- Diameter >6 and <45 cm will be destined to Sawn Wood.
- Diameter ≥ 45 cm will be destined to Wood-based panels.

Based on the yield tables, it is not expected to achieve a diameter higher than 45 cm, excluding the wood-based panels of the wood products in the Germany pilot sites.

Taking this as parameter we can relate with the treatments that will be carried out:

- 30 years: once the thinning will cut all the trees <5cm, all the trees will have ≤ 6 cm, so, all the volume will be destined to Fiberboard and Pulp.
- 50 years: all the trees bellow 10 cm will be thinned, considering the 10cm as the number of the diameter, the proportion that would be destined to Fiberboard and Pulp and the portion to Sawn Wood can be estimated, by using different models and tools (CUBIFOR from CESEFOR). Based on that the 75% of the trees is destined to Fiberboard/Pulp and the 25% to the Sawn Wood.
- Final cut: For the *Pinus sylvestris*, following the yield table, at the age of final cut the diameter will vary between 25-30 cm. In that case, the 10% will be used for Fiberboard/Pulp and 90% for Sawn Wood. In the case of *P. abies*, the final diameter varies between 16-20 cm, in which case a proportion of 40% will be destined for Fiberboard/Pulp and 60% for Sawn Wood.

3.2.4.2 Greece

As far as the Greek pilot sites are concerned, final clear cuttings would be normally performed at the time when carbon stocking will have reached the maximum state. However, the remaining question will be where the products will become absorbed within the Greek market and what is the framework of market demand and use of wood products of these forest species. At present, two facts shape the Greek state of silviculture management and use of wood products from oak and coniferous species

(a) oak forests are gradually degraded but when cuttings are performed in these forests their wood usually ends up in fuelwood that is mainly used for heating in countryside houses

(b) wood from coniferous species in Greece is of poor quality as mentioned earlier

For this reason, it is suggested that afforestation modules in the Greek pilot MLs sites will take into account that on one hand wood for fuelwood will not be harvested from oak afforestations and that on the other hand, afforestations with Pinus species will be logged down to wood that will be used as fuelwood in the form of pellets. Pellets that are made from wood of coniferous species is of finest quality because the raw material is softwood and contains resins that can be easily manipulated into pellet product with optimized fuel properties. At the end, this would be a win-win process as oak forests in MLs will not be depleted for fuelwood but will be managed and conserved as carbon sinks, while coniferous forests will be managed to produce pellets of very good quality that may gradually substitute fossil fuel sources of energy for heating (e.g. use of petrol). Softwood pellets actually have 10-20% more BTU per weight than hardwood pellets because softwoods have resins in them that have a higher heating value than wood fiber. MLs with pine plantings in Greece make an attractive choice for efficient and sustainable production of softwood wood material for fuelwood with a better market uptake potential in the long-term future than timber for other categories of wood products. Launching the use of pellets in the Greek countryside, where MLs will be reforested under this concept with pine species, implies changes in the legal framework of house construction, with a shift to issuing permits for installation of pellet burners in house constructions in place of petrol burners that currently exist.

In terms of the Greek wood market industry, a general estimation for the participation of the three semi-finished wood product commodity classes (sawnwood, wood-based panels, paper and paperboard) plus wood fuel is that 50% will be destined at wood pellets while the other 50% will be shared towards sawdust for wood-based panels. Therefore, the share of the estimated carbon to be stored in the wood products will follow this logic.

3.2.4.3 Poland

Based on figure 4, section 2.2, which has as reference the paper from Węgiel A. it is possible to establish some thresholds that will guide the destination of the trees to wood products related with the *Pinus sylvestris* and which will be also considered to *Quercus spp* species:

- Diameter ≤ 5 cm will be destined to Fiberboard and Pulp.
- Diameter >15 and <45 cm will be destined to Sawn Wood.
- Diameter ≥ 45 cm will be destined to Wood-based panels.

Based on the yield tables is not expected to achieve a diameter higher than 45 cm, excluding the wood-based panels of the wood products in the Poland pilot sites.

Taking this as parameter we can relate with the treatments that will be carried out, similar as on the Germany pilot site:

- 30 years: once the thinning will cut all the trees <5 cm, all the trees will be allocated on the Fiberboard/Pulp threshold, so, all the volume will be destined to Fiberboard and Pulp.
- 50 years: For the ML1 and ML2, all the trees bellow 10 cm will be thinned, considering the 10 cm as the diameter, the proportion that would be destinated to Fiberboard and Pulp and the portion to Sawn Wood can be estimated, by using different models and tools (CUBIFOR from CESEFOR). Based on that the 75% of the trees is destinated for Fiberboard/Pulp and the 25% for Sawn Wood.

- Final cut: For the *Pinus sylvestris* and *Quercus spp* following the yield table, at the age of final cut the diameter will vary between 20-30 cm. In that case, the 10% will be for Fiberboard/Pulp and the 90% for Sawn Wood.

3.2.4.4 Spain

In terms of the Spanish wood market industry, a general estimation for the participation of the three semi-finished wood product commodity classes (sawnwood, wood-based panels, paper and paperboard) is that approximately 50% of the wood volume will be used for the production of sawn wood, while the other 15% - 25% will be shared towards wood-based panels, depending on the species and SI of the pilot site. The remaining percentage of HWPs, ranging between 25% to 35% will produce wood chips and wood particles. These estimations are based on the HWP volumes calculated using CubiFOR v.2.Therefore, the share of the estimated carbon to be stored in the wood products will follow this logic.

3.2.5 Biomass and Carbon of final wood product

Following the threshold that was defined in section 3.2.3 one table was generated with a volume prediction of biomass destined for each product and depending on the site quality. Also to increase the accuracy of the values, the factor loss of each process was considered (FAO,2020).

3.2.5.1 Germany

On the Germany sites the factor was retrieved from the literature, focusing on achieving better estimation accuracy (Table 36).

Table 36. Factor loss on the wood product production for the Germany area.

Wood Product	Factor
Pulp and Fiberboard	2.45
Sawn wood	1.67
Panel	1.82

Table 37. Final wood biomass of each species due the factor loss of the wood product on the Marginal Land 1 in Germany pilot site.

Marginal Land 01									
Species	**Year**	**Threshold**	**Proportion**	**Wood Product**	**Factor Loss**	**Volume Total**	**Volume Wood Product**	**Specific Gravity**	**Biomass**
		cm				**m3/ha**	**m3/ha**		**tn/ha**
Pinus sylvestris	30	<5	1	Pulp-Fiberboard	2.45	5.2	2.12	0.45	0.952
Picea abies	30	<5	1	Pulp-Fiberboard	2.45	2.832	1.16	0.43	0.496
Pinus sylvestris	50	<10	0.6	Pulp-Fiberboard	2.45	12.96	5.29	0.45	2.373
Pinus sylvestris	50	<10	0.4	Sawn wood	1.67	8.64	5.17	0.45	2.321
Picea abies	50	<10	0.6	Pulp-Fiberboard	2.45	13.88	5.67	0.43	2.429
Picea abies	50	<10	0.4	Sawn wood	1.67	9.25	5.54	0.43	2.375
Pinus sylvestris	End		0.1	Pulp-Fiberboard	2.45	17.2	7.02	0.45	3.150
Pinus sylvestris	End		0.9	Sawn wood	1.67	154	92.22	0.45	41.373
Picea abies	End		0.4	Pulp-Fiberboard	2.45	112.46	45.90	0.43	19.679
Picea abies	End		0.6	Sawn wood	1.67	168.69	101.01	0.43	43.305

Table 38. Final wood biomass of each species due the factor loss of the wood product on the Marginal Land 2 in Germany pilot site.

Marginal Land 02									
Species	**Year**	**Threshold**	**Proportion**	**Wood Product**	**Factor Loss**	**Volume Total**	**Volume Wood Product**	**Specific Gravity**	**Biomass**
		cm				**m3/ha**	**m3/ha**		**tn/ha**
Pinus sylvestris	30	<5	1	Pulp-Fiberboard	2.45	4.4	1.79	0.45	0.805
Picea abies	30	<5	1	Pulp-Fiberboard	2.45	2.046	0.83	0.43	0.357
Pinus sylvestris	50	<10	0.6	Pulp-Fiberboard	2.45	11.28	4.60	0.45	2.07
Pinus sylvestris	50	<10	0.4	Sawn wood	1.67	7.52	4.50	0.45	2.025
Picea abies	50	<10	0.6	Pulp-Fiberboard	2.45	7.24	2.95	0.43	1.268
Picea	50	<10	0.4	Sawn	1.67	4.83	2.89	0.43	1.242

abies				wood					
Pinus sylvestris	End		0.1	Pulp-Fiberboard	2.45	14.92	6.09	0.45	2.740
Pinus sylvestris	End		0.9	Sawn wood	1.67	134.28	80.41	0.45	36.184
Picea abies	End		0.4	Pulp-Fiberboard	2.45	76.74	31.32	0.43	13.467
Picea abies	End		0.6	Sawn wood	1.67	115.11	68.92	0.43	29.635

Based on that, it is possible to divide the total biomass to be destined on each specific product type during the different years' treatments and final harvesting. An important point that needs to be considered is that the final wood product has a lot of interference with the market demand, which will change some of the estimated values of the final wood product in the area.

Table 39. Biomass to each wood product for each year of intervention:

	Biomass tn/ha - ML 1		Biomass tn/ha - ML 2	
Year	**Pulp-Fiberboard**	**Sawn wood**	**Pulp-Fiberboard**	**Sawn wood**
30	1.45	0	1.16	0
50	4.80	4.70	3.33	3.26
Final	22.83	84.68	16.16	65.62
Total	29.08	89.37	20.66	68.89

Considering the information presented on table 38 it is possible to conclude that the Marginal Land 1 will have a total of 118.45 tn/ha of biomass in two different wood products, of which 89.37 tn/ha is in sawn wood and 29.08 tn/ha is destinated to pulp/fiberboard. In the other hand the Marginal Land 2 has a total of 89.54 tn/ha of biomass, of which 68.89 tn/ha is related to the sawn wood and 20.66 tn/ha is the pulp/fiberboard.

3.2.5.2 Greece

The biomass and carbon estimations for *Pinus brutia* and *Pinus halepensis* was calculated based on Montero's yield table (2000) and the reforestation modules in the Greek pilot sites for MLs, using linear interpolation. The results are shown in the tables below, according to the number of trees throughout the years of monitoring the production for the no thinning (Table 40) and thinning scenario (Table 41).

Pinus halepensis

Table 40. Biomass and Carbon estimation for *Pinus halepensis* for the aboveground and belowground components and total tree for the no thinning scenario,

Yield estimation data	Quality	Age	N	V	V	ABG C (kg)/tree				C AGB	C BGB	Total C	Total C
		years	*tree/ ha*	*m³/ ha*	*dm³/ tree*	*branch >7cm*	*branch 2-7cm*	*branch < 2cm*	*Stem*	*kg/ tree*	*kg/ tree*	*kg/ tree*	*kg/ ha*
Montero	11	30	2,038	30.2	14.8	1.2	1	2.6	4.5	9.3	2.9	12.2	24,859.9
MLs			1,500	22.2	10.9	0.9	0.7	1.9	3.3	6.8	2.1	9.0	18,297.3
Montero	11	50	1,305	65.8	50.4	4.1	3.5	8.8	15.3	31.7	9.8	41.5	54,164.9
MLs			1,200	60.5	46.3	3.8	3.2	8.1	14.1	29.1	9.0	38.2	49,806.8
Montero	11	90	766	106.5	139	11.2	9.6	24.3	42.3	87.4	27	114.4	87,668
MLs			960	133.5	174.2	14.0	12.0	30.5	53.0	109.5	33.8	143.4	109,871.1
Montero	14	30	1,481	53.3	36	2.9	2.5	6.3	11	22.6	7	29.6	43,875.2
MLs			1,250	45.0	30.4	2.4	2.1	5.3	9.3	19.1	5.9	25.0	37,031.7
Montero	14	50	1,006	107.1	106.5	8.6	7.4	18.6	32.4	67	20.7	87.6	88,161.9
MLs			1,000	106.5	105.9	8.5	7.4	18.5	32.2	66.6	20.6	87.1	87,636.1
Montero	14	90	608	165.5	272.2	21.9	18.8	47.6	82.9	171.2	52.9	224.1	136,235.3
MLs			800	217.8	358.2	28.8	24.7	62.6	109.1	225.3	69.6	294.9	179,257.0

Table 41. Biomass and Carbon estimation for *Pinus halepensis* for the aboveground and belowground components and total tree for the thinning scenario,

Yield estimation data	Quality	State	Age	N	V	V	ABG C (kg)/tree				C AGB	C BGB	Total C	Total C
			years	*tree/ ha*	*m³/ ha*	*dm³/ tree*	*branch >7cm*	*branch 2-7cm*	*branch < 2cm*	*Stem*	*kg/ tree*	*kg/ tree*	*kg/ tree*	*kg/ ha*
Montero	11	Before thinning	30	2,038	30.2	14.8	1.2	1	2.6	4.5	9.3	2.9	12.2	24,859.9
MLs				1,500	22.2	10.9	0.9	0.7	1.9	3.3	6.8	2.1	9.0	18,297.3
Montero	11	Thinning	30	86	0.3	3.5	0.3	0.2	0.6	1.1	2.2	0.7	2.9	247
MLs				150	0.5	6.1	0.5	0.3	1.0	1.9	3.8	1.2	5.1	430.8
Montero	11	After thinning	30	1,952	30.1	15.4	1.2	1.1	2.7	4.7	9.7	3	12.7	24,777.5
MLs				1,350	20.8	10.7	0.8	0.8	1.9	3.3	6.7	2.1	8.8	17,136.1
Montero	11	Before thinning	50	1,305	65.8	50.4	4.1	3.5	8.8	15.3	31.7	9.8	41.5	54,164.9
MLs				1,080	54.5	41.7	3.4	2.9	7.3	12.7	26.2	8.1	34.3	44,826.1
Montero	11	Before thinning	90	766	106.5	139	11.2	9.6	24.3	42.3	87.4	27	114.4	87668
MLs				864	120.1	156.8	12.6	10.8	27.4	47.7	98.6	30.5	129.0	98,884.0
Montero	14	Before thinning	30	1,481	53.3	36	2.9	2.5	6.3	11	22.6	7	29.6	43,875.2
MLs				1,250	45.0	30.4	2.4	2.1	5.3	9.3	19.1	5.9	25.0	37,031.7

Montero	14	Thinning	30	86	0.3	3.5	0.7	0.6	1.5	2.6	5.4	1.7	7.1	987.8
MLs				125	0.4	5.1	0.4	0.3	0.9	1.6	3.2	1.0	4.2	359.0
Montero	14	After thinning	30	1,952	30.1	15.4	3.1	2.7	6.8	11.8	24.4	7.5	32	42,887.4
MLs				1,125	17.3	8.9	0.7	0.6	1.6	2.7	5.6	1.7	7.3	14,280.1
Montero	14	Before thinning	50	1,006	107.1	106.5	8.6	7.4	18.6	32.4	67	20.7	87.6	88,161.9
MLs				900	95.8	95.3	7.7	6.6	16.6	29.0	59.9	18.5	78.4	78,872.5
Montero	14	Before thinning	90	608	165.5	272.2	21.9	18.8	47.6	82.9	171.2	52.9	224.1	136,235.3
MLs				720	196.0	322.3	25.9	22.3	56.4	98.2	202.7	62.6	265.4	161,331.3

The biomass and carbon estimations for *Quercus frainetto* were based on Kossenaki's yield table (1939) and the reforestation modules in the Greek pilot sites for MLs, using linear extrapolation. The results are shown in the table below, according to the number of trees throughout the years of monitoring the production (Table 42).

Quercus frainetto

Table 42. Biomass and Carbon estimation for *Quercus frainetto* for the aboveground and belowground components and total tree, only no thinning scenario

Yield estimation data	Quality	Age	N	V	V	ABG C (kg)/tree				C AGB	C BGB	Total C	Total C
		years	*tree/ ha*	*m³/ ha*	*dm³/ tree*	*Foliage*	*Branch*	*Bark*	*Stem*	*kg/ tree*	*kg/ tree*	*kg/ tree*	*kg/ha*
Kossenakis	Va	30	5,900	53.2	6.67	0.79	1.2	0.92	3.76	6.7	1.87	8.57	50,563.0
MLs			2,250	20.3									19,282.5
Kossenakis	Va	45	4,300	67.7	11.65	1.38	2.1	1.61	6.56	11.7	3.26	14.96	64,328.0
MLs			2,025	31.9									30,294.0
Kossenakis	Va	90	3,870	109.2	20.89	2.48	3.76	2.89	11.75	20.9	5.85	26.75	103,522.5
MLs			1,822	51.4									48,738.5

3.2.5.3 Poland

On the Poland sites the factor was retrieved from the literature, focusing on achieving better estimation accuracy (Table 43).

Table 43. Factor loss on the wood product production for the Poland area.

Wood Product	Factor
Pulp and Fiberboard	2.45
Sawn wood – *P. sylvestris*	1.64

Sawn wood – *Quercus*	1.59
Panel	1.95

Table 44. Final wood biomass of each species due the factor loss of the wood product on the Marginal Land 1 in Poland pilot site.

Marginal Land 01									
Species	**Year**	**Threshold**	**Proportion**	**Wood Product**	**Factor Loss**	**Volume Total**	**Volume Wood Product**	**Specific Gravity**	**Biomass**
		cm				**m3/ha**	**m3/ha**		**tn/ha**
Pinus sylvestris	30	<5	1	Pulp-Fiberboard	2.45	10.48	4.28	0.45	1.919
Quercus spp.	30	<5	1	Pulp-Fiberboard	2.45	45.53	18.58	0.43	7.967
Pinus sylvestris	50	<10	0.6	Pulp-Fiberboard	2.45	32.04	13.08	0.45	5.867
Pinus sylvestris	50	<10	0.4	Sawn wood	1.64	10.68	6.51	0.45	2.922
Quercus spp.	50	<10	0.6	Pulp-Fiberboard	2.45	89.25	36.43	0.43	15.617
Quercus spp.	50	<10	0.4	Sawn wood	1.59	29.75	18.71	0.43	8.021
Pinus sylvestris	End		0.1	Pulp-Fiberboard	2.45	31.33	12.79	0.45	5.737
Pinus sylvestris	End		0.9	Sawn wood	1.64	281.99	171.95	0.45	77.143
Quercus spp.	End		0.4	Pulp-Fiberboard	2.45	94.156	38.43	0.43	16.476
Quercus spp.	End		0.6	Sawn wood	1.59	847.4	532.96	0.43	228.484

Table 45. Final wood biomass of each species due the factor loss of the wood product on the Marginal Land 2 in Poland pilot site.

Marginal Land 02									
Species	**Year**	**Threshold**	**Proportion**	**Wood Product**	**Factor Loss**	**Volume Total**	**Volume Wood Product**	**Specific Gravity**	**Biomass**
		cm				**m3/ha**	**m3/ha**		**tn/ha**
Pinus sylvestris	30	<5	1	Pulp-Fiberboard	2.45	12.98	5.30	0.45	2.377
Quercus spp.	30	<5	1	Pulp-Fiberboard	2.45	38.17	15.58	0.43	6.679
Pinus sylvestris	50	<10	0.6	Pulp-Fiberboard	2.45	32.15	13.12	0.45	5.887
Pinus sylvestris	50	<10	0.4	Sawn wood	1.64	10.705	6.53	0.45	2.929
Quercus spp.	50	<10	0.6	Pulp-Fiberboard	2.45	98.7	40.29	0.43	17.271
Quercus spp.	50	<10	0.4	Sawn wood	1.59	32.9	20.69	0.43	8.871
Pinus sylvestris	End		0.1	Pulp-Fiberboard	2.45	25.215	10.29	0.45	4.617
Pinus sylvestris	End		0.9	Sawn wood	1.64	226.93	138.37	0.45	62.081
Quercus spp.	End		0.4	Pulp-Fiberboard	2.45	81.29	33.18	0.43	14.224
Quercus spp.	End		0.6	Sawn wood	1.59	731.69	460.18	0.43	197.285

Based on the previous tables (Table 44, 45), it is possible to divide the total biomass to be destinated on each specific product type during the different years' treatments and final harvesting. As it was mentioned before and is a point very highlighted on this deliverable, the market demand plays an important role on the wood products. It is important to point that the Poland yield tables have no detailed information of the harvestings resulting in more estimations related to the innervations. It should be noted that the values related to the carbon and biomass per hectare are greater than the Germany pilot sites, which is also related with the number of trees per hectare that will be planted, and also the growth on this area (Table 46).

Table 46. Biomass to each wood product for each year of intervention:

	Biomas tn/ha - ML 1		Biomas tn/ha - ML 2	
Year	**Pulp-Fiberboard**	**Sawn wood**	**Pulp-Fiberboard**	**Sawn wood**
30	9.89		9.06	
50	21.48	10.94	23.16	11.80
Final	22.21	305.63	18.84	259.37
Total	53.58	316.57	51.06	271.16

3.2.5.4 Spain

The carbon values for the Spanish test sites are given in 3 pools, above ground carbon, below ground carbon and total carbon per tree and hectare. Additionally, the above ground carbon is divided in values branches, foliage and stem, as shown in Table 47, Table 48, Table 49 and Table 50.

Table 47. Biomass and Carbon estimation for *Pinus pinaster* for the aboveground and belowground components and total tree.

Quality	State	Age	N	V	V	ABG C (kg)/tree				C AGB	C BGB	Total C	Total C
		years	tree/ ha	m^3/ ha	dm^3/ tree	branch >7cm	branch 2-7cm	branch < 2cm	Stem	kg/ tree	kg/ tree	kg/ tree	kg/ ha
12	Before thinning	40	1500	92.8	61.9	0.2	1.1	2.9	16.4	20.7	5.9	26.5	39816.9
12	Before thinning	50	925	135.7	146.7	0.6	2.6	6.9	39.0	49.0	13.9	62.9	58223.7
12	Before thinning	65	550	178.0	323.6	1.3	5.7	15.1	86.0	108.2	30.7	138.9	76373.0
12	Before thinning	80	400	201.8	504.5	2.0	8.9	23.6	134.1	168.6	47.8	216.5	86584.6
12	Thinning	40	575	29.4	51.1	0.2	0.9	2.4	13.6	17.1	4.8	21.9	12614.4
12	Thinning	50	375	42.4	113.1	0.5	2.0	5.3	30.0	37.8	10.7	48.5	18192.2
12	Thinning	65	150	40.1	267.3	1.1	4.7	12.5	71.0	89.4	25.3	114.7	17205.4
12	After thinning	40	925	63.4	68.5	0.3	1.2	3.2	18.2	22.9	6.5	29.4	27202.5
12	After thinning	50	550	93.2	169.5	0.7	3.0	7.9	45.0	56.6	16.1	72.7	39988.5
12	After thinning	65	400	137.9	344.8	1.4	6.1	16.1	91.6	115.2	32.7	147.9	59167.6
15	Before thinning	35	1500	119.4	79.6	0.7	2.0	2.1	22.5	31.5	8.6	40.1	60187.0
15	Before thinning	45	925	182.8	197.6	1.8	5.0	5.2	55.8	78.3	21.3	99.6	92145.7
15	Before thinning	60	550	245.9	447.1	4.0	11.4	11.9	126.3	177.1	48.2	225.4	123953.1
15	Before thinning	75	350	279.6	798.9	7.2	20.3	21.2	225.7	316.5	86.2	402.7	140940.5
15	Thinning	35	575	37.8	65.7	0.6	1.7	1.7	18.6	26.0	7.1	33.1	19054.2
15	Thinning	45	375	57.2	152.5	1.4	3.9	4.1	43.1	60.4	16.5	76.9	28833.3
15	Thinning	60	200	73.8	369.0	3.3	9.4	9.8	104.2	146.2	39.8	186.0	37201.0
15	Stand after	35	925	81.6	88.2	0.8	2.2	2.3	24.9	35.0	9.5	44.5	41132.9

Quality	State	Age	N	V	V	ABG C (kg)/tree				C AGB	C BGB	Total C	Total C
		years	tree/ ha	m³/ ha	dm³/ tree	branch >7cm	branch 2-7cm	branch < 2cm	Stem	kg/ tree	kg/ tree	kg/ tree	kg/ ha
	thinning												
15	Stand after thinning	45	550	125.6	228.4	2.1	5.8	6.1	64.5	90.5	24.6	115.1	63312.3
15	Stand after thinning	60	350	172.1	491.7	4.4	12.5	13.1	138.9	194.8	53.0	247.9	86752.0

Table 48. Biomass and Carbon estimation for *Pinus nigra* for the aboveground and belowground components and total tree.

Quality	State	Age	N	V	V	ABG C (kg)/tree				C AGB	C BGB	Total C	Total C
		years	tree/ ha	m³/ ha	dm³/ tree	branch >7cm	branch 2-7cm	branch < 2cm	Stem	kg/ tree	kg/ tree	kg/ tree	kg/ ha
12	Before thinning	40	1500	161.1	107.4	3.6	5.3	10.6	33.9	53.3	13.0	66.3	99424.1
12	Before thinning	50	1000	233.7	233.7	7.8	11.5	23.0	73.8	116.0	28.3	144.2	144229.8
12	Before thinning	65	650	263.1	404.8	13.5	19.9	39.8	127.7	200.8	49.0	249.8	162374.2
12	Before thinning	80	425	234.2	551.1	18.3	27.1	54.1	173.9	273.4	66.7	340.1	144538.4
12	Thinning	40	500	42.8	85.6	2.8	4.2	8.4	27.0	42.5	10.4	52.8	26414.4
12	Thinning	50	350	62.3	178.0	5.9	8.7	17.5	56.2	88.3	21.5	109.9	38448.9
12	Thinning	65	225	66.3	294.7	9.8	14.5	28.9	93.0	146.2	35.6	181.9	40917.6
12	After thinning	40	1000	118.3	118.3	3.9	5.8	11.6	37.3	58.7	14.3	73.0	73009.8
12	After thinning	50	650	171.3	263.5	8.8	12.9	25.9	83.2	130.8	31.9	162.6	105719.2
12	After thinning	65	425	196.9	463.3	15.4	22.8	45.5	146.2	229.9	56.0	285.9	121518.4
15	Before thinning	40	1500	220.0	146.7	1.3	3.7	3.9	41.4	58.1	15.8	73.9	110897.4
15	Before thinning	55	950	313.3	329.8	3.0	8.4	8.8	93.2	130.7	35.6	166.2	157928.0
15	Before thinning	70	600	338.6	564.3	5.1	14.3	15.0	159.4	223.6	60.9	284.5	170681.2
15	Before thinning	80	400	299.8	749.5	6.8	19.1	19.9	211.7	297.0	80.9	377.8	151122.9
15	Thinning	40	550	64.3	116.9	1.1	3.0	3.1	33.0	46.3	12.6	58.9	32412.3
15	Thinning	55	350	88.0	251.4	2.3	6.4	6.7	71.0	99.6	27.1	126.7	44359.0
15	Thinning	70	200	82.1	410.5	3.7	10.4	10.9	116.0	162.6	44.3	206.9	41384.9
15	Stand after thinning	40	950	155.6	163.8	1.5	4.2	4.3	46.3	64.9	17.7	82.6	78434.7
15	Stand after thinning	55	600	225.4	375.7	3.4	9.6	10.0	106.1	148.8	40.5	189.4	113619.4
15	Stand after thinning	70	400	256.5	641.3	5.8	16.3	17.0	181.1	254.1	69.2	323.2	129296.3

Table 49. Biomass and Carbon estimation for *Pinus sylvestris* for the aboveground and belowground components and total tree.

Quality	State	Age	N	V	V	ABG C (kg)/tree	C AGB	C BGB	Total C	Total C

		years	tree/ ha	m^3/ ha	dm^3/ tree	branch >7cm	branch 2-7cm	branch < 2cm	Stem	kg/ tree	kg/ tree	kg/ tree	kg/ ha
12	Before thinning	40	1500	114.6	76.4	0.7	1.9	2.0	21.6	30.3	8.2	38.5	57767.5
12	Before thinning	55	1000	175.8	175.8	1.6	4.5	4.7	49.7	69.7	19.0	88.6	88617.1
12	Before thinning	70	625	182.8	292.5	2.6	7.4	7.8	82.6	115.9	31.6	147.4	92145.7
12	Before thinning	110	450	241	535.6	4.8	13.6	14.2	151.3	212.2	57.8	270.0	121483.1
12	Thinning	40	500	30.9	61.8	0.6	1.6	1.6	17.5	24.5	6.7	31.2	15576.0
12	Thinning	55	375	48.6	129.6	1.2	3.3	3.4	36.6	51.3	14.0	65.3	24498.2
12	Thinning	70	175	42.3	241.7	2.2	6.1	6.4	68.3	95.8	26.1	121.8	21322.5
12	Stand after thinning	40	1000	83.7	83.7	0.8	2.1	2.2	23.6	33.2	9.0	42.2	42191.4
12	Stand after thinning	55	625	127.2	203.5	1.8	5.2	5.4	57.5	80.6	22.0	102.6	64118.9
12	Stand after thinning	70	450	140.5	312.2	2.8	7.9	8.3	88.2	123.7	33.7	157.4	70823.1
15	Before thinning	35	1500	136.5	91.0	0.8	2.3	2.4	25.7	36.1	9.8	45.9	68806.8
15	Before thinning	50	950	214.7	226.0	2.0	5.7	6.0	63.8	89.5	24.4	113.9	108225.8
15	Before thinning	65	575	234.8	408.3	3.7	10.4	10.8	115.4	161.8	44.0	205.8	118357.8
15	Before thinning	110	400	315.2	788.0	7.1	20.0	20.9	222.6	312.2	85.0	397.2	158885.7
15	Thinning	35	550	40.4	73.5	0.7	1.9	2.0	20.8	29.1	7.9	37.0	20364.8
15	Thinning	50	375	62.4	166.4	1.5	4.2	4.4	47.0	65.9	18.0	83.9	31454.5
15	Thinning	65	175	59.1	337.7	3.1	8.6	9.0	95.4	133.8	36.4	170.2	29791.1
15	Stand after thinning	35	950	96.1	101.2	0.9	2.6	2.7	28.6	40.1	10.9	51.0	48442.0
15	Stand after thinning	50	575	152.3	264.9	2.4	6.7	7.0	74.8	104.9	28.6	133.5	76771.2
15	Stand after thinning	65	400	175.7	439.3	4.0	11.2	11.7	124.1	174.0	47.4	221.4	88566.7

Table 50. Biomass and Carbon estimation for *Pinus halepensis* for the aboveground and belowground components and total tree.

Quality	State	Age	N	V	V	ABG C (kg)/tree				C AGB	C BGB	Total C	Total C
		years	*tree/ ha*	*m^3/ ha*	*dm^3/ tree*	*branch >7cm*	*branch 2-7cm*	*branch < 2cm*	*Stem*	*kg/ tree*	*kg/ tree*	*kg/ tree*	*kg/ ha*
11	Before thinning	20	2103	12.9	6.1	0.5	0.4	1.1	1.9	3.9	1.2	5	10618.9
11	Before thinning	30	2038	30.2	14.8	1.2	1	2.6	4.5	9.3	2.9	12.2	24859.9
11	Before thinning	40	1952	51.2	26.2	2.1	1.8	4.6	8	16.5	5.1	21.6	42146.5
11	Before thinning	50	1305	65.8	50.4	4.1	3.5	8.8	15.3	31.7	9.8	41.5	54164.9
11	Before thinning	60	1233	82.7	67.1	5.4	4.6	11.7	20.4	42.2	13	55.2	68076.5
11	Before thinning	70	1005	92.5	92	7.4	6.4	16.1	28	57.9	17.9	75.8	76143.6
11	Before thinning	80	862	100.3	116.4	9.4	8	20.3	35.4	73.2	22.6	95.8	82564.4
11	Before thinning	90	766	106.5	139	11.2	9.6	24.3	42.3	87.4	27	114.4	87668
11	Before thinning	100	699	111.5	159.5	12.8	11	27.9	48.6	100.3	31	131.3	91783.9

Quality	State	Age	N	V	V	ABG C (kg)/tree				C AGB	C BGB	Total C	Total C
		years	*tree/ ha*	*m^3/ ha*	*dm^3/ tree*	*branch >7cm*	*branch 2-7cm*	*branch < 2cm*	*Stem*	*kg/ tree*	*kg/ tree*	*kg/ tree*	*kg/ ha*
11	Before thinning	110	650	115.6	177.8	14.3	12.3	31.1	54.1	111.8	34.6	146.4	95158.9
11	Before thinning	120	613	118.9	194	15.6	13.4	33.9	59	122	37.7	159.7	97875.4
11	Thinning	20	65	0.1	1.5	0.1	0.1	0.3	0.5	1	0.3	1.3	82.3
11	Thinning	30	86	0.3	3.5	0.3	0.2	0.6	1.1	2.2	0.7	2.9	247
11	Thinning	40	647	3.6	5.6	0.4	0.4	1	1.7	3.5	1.1	4.6	2963.4
11	Thinning	50	72	4.5	62.5	5	4.3	10.9	19	39.3	12.1	51.4	3704.3
11	Thinning	60	227	9.3	41	3.3	2.8	7.2	12.5	25.8	8	33.7	7655.5
11	Thinning	70	143	13.7	95.8	7.7	6.6	16.7	29.2	60.3	18.6	78.9	11277.5
11	Thinning	80	96	17.6	183.3	14.8	12.7	32.1	55.8	115.3	35.6	150.9	14487.9
11	Thinning	90	67	21	313.4	25.2	21.7	54.8	95.4	197.1	60.9	258	17286.7
11	Thinning	100	49	23.8	485.7	39.1	33.6	84.9	147.8	305.5	94.4	399.8	19591.5
11	Thinning	110	37	26.2	708.1	57	49	123.8	215.5	445.3	137.6	582.9	21567.2
11	Thinning	120	–	–	–	–	–	–	–	–	–	–	–
11	After thinning	20	2038	13	6.4	0.5	0.4	1.1	1.9	4	1.2	5.3	10701.3
11	After thinning	30	1952	30.1	15.4	1.2	1.1	2.7	4.7	9.7	3	12.7	24777.5
11	After thinning	40	1305	47.1	36.1	2.9	2.5	6.3	11	22.7	7	29.7	38771.5
11	After thinning	50	1233	64.8	52.6	4.2	3.6	9.2	16	33.1	10.2	43.3	53341.7
11	After thinning	60	1005	77.5	77.1	6.2	5.3	13.5	23.5	48.5	15	63.5	63796
11	After thinning	70	862	87.8	101.9	8.2	7	17.8	31	64.1	19.8	83.8	72274.7
11	After thinning	80	766	96.1	125.5	10.1	8.7	21.9	38.2	78.9	24.4	103.3	79107
11	After thinning	90	699	102.9	147.2	11.9	10.2	25.7	44.8	92.6	28.6	121.2	84704.6
11	After thinning	100	650	108.5	166.9	13.4	11.5	29.2	50.8	105	32.4	137.4	89314.4
11	After thinning	110	613	113	184.3	14.8	12.8	32.2	56.1	115.9	35.8	151.7	93018.7
11	After thinning	120	–	–	–	–	–	–	–	–	–	–	–
14	Before thinning	20	1586	24.7	15.6	1.3	1.1	2.7	4.7	9.8	3	12.8	20332.4
14	Before thinning	30	1481	53.3	36	2.9	2.5	6.3	11	22.6	7	29.6	43875.2
14	Before thinning	40	1342	85	63.3	5.1	4.4	11.1	19.3	39.8	12.3	52.1	69969.8
14	Before thinning	50	1006	107.1	106.5	8.6	7.4	18.6	32.4	67	20.7	87.6	88161.9
14	Before thinning	60	977	134.5	137.7	11.1	9.5	24.1	41.9	86.6	26.7	113.3	110716.9
14	Before thinning	70	797	147.2	184.7	14.9	12.8	32.3	56.2	116.2	35.9	152	121171.2
14	Before thinning	80	684	157.4	230.1	18.5	15.9	40.2	70	144.7	44.7	189.4	129567.6
14	Before thinning	90	608	165.5	272.2	21.9	18.8	47.6	82.9	171.2	52.9	224.1	136235.3
14	Before thinning	100	554	172	310.5	25	21.5	54.3	94.5	195.3	60.3	255.6	141585.9
14	Before thinning	110	515	177.3	344.3	27.7	23.8	60.2	104.8	216.5	66.9	283.4	145948.8
14	Before thinning	120	486	181.6	373.7	30.1	25.8	65.3	113.7	235	72.6	307.6	149488.4
14	Thinning	20	65	0.1	1.5	0.2	0.1	0.3	0.6	1.2	0.4	1.6	164.6
14	Thinning	30	86	0.3	3.5	0.7	0.6	1.5	2.6	5.4	1.7	7.1	987.8

Quality	State	Age	N	V	V	ABG C (kg)/tree				C AGB	C BGB	Total C	Total C
		years	*tree/ ha*	*m³/ ha*	*dm³/ tree*	*branch >7cm*	*branch 2-7cm*	*branch < 2cm*	*Stem*	*kg/ tree*	*kg/ tree*	*kg/ tree*	*kg/ ha*
14	Thinning	40	647	3.6	5.6	2	1.7	4.3	7.4	15.3	4.7	20.1	6750
14	Thinning	50	72	4.5	62.5	25.8	22.2	56.1	97.6	201.7	62.3	264	7655.5
14	Thinning	60	227	9.3	41	8.8	7.6	19.1	33.3	68.8	21.3	90.1	16216.5
14	Thinning	70	143	13.7	95.8	20.4	17.6	44.4	77.3	159.7	49.3	209.1	23625.1
14	Thinning	80	96	17.6	183.3	38.4	33	83.5	145.4	300.4	92.8	393.2	29881.2
14	Thinning	90	67	21	313.4	64.7	55.6	140.5	244.7	505.5	156.1	661.6	35067.2
14	Thinning	100	49	23.8	485.7	98.9	85	214.7	373.9	772.4	238.6	1011	39430
14	Thinning	110	37	26.2	708.1	145.5	125	315.9	550	1136.4	351	1487.4	43134.3
14	Thinning	120	–	–	–	–	–	–	–	–	–	–	–
14	After thinning	20	2038	13	6.4	1.3	1.2	2.9	5.1	10.5	3.2	13.7	20332.4
14	After thinning	30	1952	30.1	15.4	3.1	2.7	6.8	11.8	24.4	7.5	32	42887.4
14	After thinning	40	1305	47.1	36.1	6.2	5.3	13.5	23.4	48.4	14.9	63.3	63713.7
14	After thinning	50	1233	64.8	52.6	8.7	7.5	19	33	68.2	21.1	89.2	87174.1
14	After thinning	60	1005	77.5	77.1	12.5	10.7	27.1	47.2	97.5	30.1	127.7	101744.3
14	After thinning	70	862	87.8	101.9	16.2	13.9	35.2	61.4	126.8	39.2	166	113515.7
14	After thinning	80	766	96.1	125.5	19.8	17	43	74.8	154.6	47.8	202.4	123064.5
14	After thinning	90	699	102.9	147.2	23.1	19.8	50.1	87.3	180.4	55.7	236.1	130802.4
14	After thinning	100	650	108.5	166.9	26	22.4	56.5	98.4	203.3	62.8	266.1	137058.5
14	After thinning	110	613	113	184.3	28.6	24.6	62.2	108.2	223.6	69.1	292.7	142244.5
14	After thinning	120	–	–	–	–	–	–	–	–	–	–	–

3.2.6 Carbon fixed by wood product (account for species specific carbon conversions)

The carbon stored in each wood product was estimated based on the above-ground biomass of each forest type, multiplied by the corresponding carbon fraction depending on the climatic zone of the pilot sites.

The default biomass conversion and expansion factors (BCEF), were selected depending on the growing stock level, forest type and climatic zone for the expansion of merchantable growing stock volume to above-ground biomass ($BCEF_S$) in tonnes of biomass per m^3 of wood volume (Table 4.5, IPCC 2006) for Greece and Spain, as shown in Table 51.

Table 51.BCEF for expansion of merchantable growing stock volume to above-ground biomass (BCEFS)

Climatic zone	Forest type	Growing stock level (m^3)				
		<20	21-40	41-100	101-200	>200
Subtropical	Pines	6.0	1.2	0.6	0.55	
	Hardwoods	5.0	1.9	0.8	0.66	
Temperate	Pines	1.8	1.0	0.75	0.7	
	Hardwoods	3.0	1.7	1.4	1.05	0.8

The default conversion factors for each HWP category were drawn from the 2019 IPCC refinement and are shown in Table 52 for Greece and Spain.

Table 52.Default conversion factors for each HWP category

HWP category	CF (Mg C/ m^3)	Source
Sawn wood (coniferous)	0.225	Table 12.1
Sawn wood (non-coniferous)	0.28	Table 12.1
Wood based panels	0.269	Table 12.1
Paper and paperboard	0.386	Table 12.1
Wood chips, wood particles, wood residues	0.229	Table 12.2

For Germany and Poland another approach was followed, which is described below.

Different studies show about the carbon fixed and stocked in the wood, as standard value from Smith et. al., 2006 and proposed by IPCC, is that the 50% of the dry wood would be carbon. With the objective to achieve better accuracy on the estimations, some different research was considered in a species-specific case and searching for studies which were carried out in similar sites like the pilot ones of the study (Table 53)

Table 53.Fraction of carbon in a dry wood per species for German and Poland sites.

Species	Fraction	Reference
Pinus sylvestris	0.47	Wegiel, 2020
Picea abies	0.50	Joosten, 2002
Quercus spp	0.49	Wutzler, 2006

Germany

Based on the table related to the carbon stocked in the dry wood it was possible to estimate the carbon for each product and the different marginal lands scenario.

Table 54.Tons of Carbon per ha fixed by wood products on Marginal Lands German Pilot site

Carbon Content (tn/ha)				
	ML 1		ML 2	
Year	Pulp-Fiberboard	Sawn wood	Pulp-Fiberboard	Sawn wood
30	0.70		0.56	
50	2.33	2.28	1.60	1.57
Final	11.32	41.10	8.00	31.73
Total	14.34	43.38	10.16	33.30

Considering the estimated carbon stocked in the dry wood of each species it was possible to estimate the carbon stocked for each product on the different Marginal Lands scenarios. In the Marginal Land 1, the total of carbon stocked on the wood products was of 57.72 tn/ha where, 43.38 tn/ha of carbon is related to the sawn wood and the 14.34 tn/ha is in pulp/fiberboard. On the Marginal Land 2, the total carbon stocked on the wood products is 43.46 tn/ha, being the more expressive amount related to sawn wood which stocks 33.30 tn/ha of carbon and the rest, which is 10.16tn/ha of carbon, is stocked on the pulp/fiberboard (Table 54).

Poland

Based on the table related to the carbon stocked in the dry wood it was possible to estimate the carbon for each product and the different marginal lands scenario (Table 55).

Table 55.Tons of Carbon per ha fixed by wood products on Marginal Lands Poland Pilot site

Carbon Content (tn/ha)				
	ML 1		ML 2	
Year	Pulp-Fiberboard	Sawn wood	Pulp-Fiberboard	Sawn wood
30	4.89		4.46	
50	10.57	5.38	11.40	5.81
Final	10.93	150.50	9.28	127.82
Total	26.39	155.88	25.14	133.63

The carbon stocked in each product is possible to be estimated based on the carbon stocked on the dry wood biomass of each species. Table 54 presents the carbon content for each wood product from the forest species on the Poland pilot site. In the Marginal Land 1, the total of carbon stocked on the wood products was of 182.27 tn/ha where, 155.88tn/ha of carbon is related to the sawn wood and the 26.39 tn/ha is in pulp/fiberboard. On the Marginal Land 2, the total carbon stocked on the wood products is of 158.77 tn/ha, being the more expressive amount related to sawn wood which stocks 133.63 tn/ha of carbon and the rest, which is 25.14 tn/ha of carbon, is stocked on the pulp/fiberboard wood product.

3.2.7 Estimation of the total C stock in wood products in the pilot site areas

The total carbon stock in the pilot sites was calculated for each marginality identification method, therefore three estimations are provided for each country (A, B and C). In case different thinning scenarios are applied, additional estimations were included.

The estimations are based on the following equation:

Equation 1. Estimation of total carbon in wood products.

$$Total\ C_{\ wood\ products} = Wood\ product\ \left(\frac{C\ tones}{ha}\right) * area\ of\ MLs\ (ha)$$

The areas used are provided in Table 16, whereas the quantities of the wood products for each scenario are described in §3.2.6.

3.2.7.1 Germany

Two different Marginal Lands scenarios were examined in Germany, one considering a high plantation suitability, with better quality sites, and another one with low plantation suitability. The total area of each Marginal Land pilot site is also presented on deliverable 4.2, section 3. Based on that the total area of Welzow area is 6,533 ha of which 1,581.1 ha are assigned to Marginal Land 1 scenario, and 4,952 ha are assigned to Marginal Land 2 scenario. The Nochten pilot site area has a total of 21,120.5 ha iof which, 1,933.4 ha are assigned to the Marginal Land 1, 14,043.5 ha are assigned the Marginal Land 2, and 5,143.6 ha are assigned as Unsuitable areas (Table 56).

Table 56. Total Biomass and Carbon stocked for each wood product in each year for the Welzow area.

Total Biomass Welzow Area (kt)				
	ML 1		ML 2	
Year	**Pulp-Fiberboard**	**Sawn wood**	**Pulp-Fiberboard**	**Sawn wood**
30	2.29		5.76	
50	7.59	7.42	16.50	16.14
final	36.09	133.88	80.03	324.97
Total	**45.98**	**141.31**	**102.29**	**341.12**
Total Carbon Welzow Area (kt)				
30	1.10		2.76	
50	3.68	3.60	7.94	7.77
final	17.90	64.98	39.61	157.13
Total	**22.68**	**68.58**	**50.31**	**164.90**

Based on the information of Table 57, is possible to affirm in the Welzow area, concerning the proposed reforestation module, that Marginal Land 1 will have a total of 45.98 kt of Pulp-Fiberboard, where 22.68 kt will be carbon, and a total of 141.31 kt of Sawn Wood, where 68.58 kt will be carbon. Marginal Land 2 will have a total of 102.29 kt of Pulp-Fiberboard, where 50.31 kt will be carbon stocked, and 341.12 kt of Sawn Wood, where 164.90 will be carbon stocked.

Table 57. Total Biomass and Carbon stocked for each wood product in each year for the Notchen area.

Total Biomass Notchen Area (kt)				
	ML 1		ML 2	
Year	**Pulp-Fiberboard**	**Sawn wood**	**Pulp-Fiberboard**	**Sawn wood**
30	2.80		5.99	
50	9.28	9.08	17.14	16.77
final	44.14	163.72	83.12	337.55
Total	**56.22**	**172.79**	**106.25**	**354.32**
Total Carbon Notchen Area (kt)				
30	1.34		2.87	
50	4.50	4.40	8.25	8.07
final	21.89	79.46	41.14	163.21
Total	**27.73**	**83.86**	**52.26**	**171.28**

Based on the information of the Table 57, is possible to affirm that in the Notchen area, concerning the proposed reforestation module, Marginal Land 1 will have a total of 56.22 kt of Pulp-Fiberboard, where 27.73 kt will be carbon, and a total of 172.29 kt of Sawn Wood, where 83.36 kt will be carbon. Marginal Land 2 will have a total of 106.25 kt of Pulp-Fiberboard, where 52.26 kt will be carbon stocked, and 354.32 kt of Sawn Wood, where 171.28 will be carbon stocked.

3.2.7.2 Greece

The wood products expected to be harvested from the Greek MLs consist of wood residues (50%), which will be used to produce pellets, and wood particles (50%). They refer exclusively to pine forests, while *Quercus frainetto* forests will be retained as a carbon pool. The wood volume is either converted to HWP or stored in the carbon pool and relevant C stock per hectare are included in Table 58 and Table 59.

Table 58. Volume (m3/ha) and C stock (tn/ ha) of HWPs in the pilot sites of Thessaloniki and Komotini, Greece for the no thinning scenario.

Species	SI	Treatments	Harvested Wood Products (m^3/ha)		Carbon pool (m^3/ha)	C stock (tn C/ha)		
			Wood chips & particles	Wood residues	Oak forest	Wood chips & particles	Wood residues	Oak forest
Pinus halepensis & Pinus brutia (100%)	11	None	66.74	66.74		18	18	
Sum			66.74	66.74		18.35	18.35	
Pinus halepensis & Pinus brutia (50%)	15	None	108.88	108.88		30	30	
Quercus frainetto (50%)	Va	None	-	-	51.42	-	-	24
Sum			108.88	108.88	51.42	30	30	24

Table 59. Volume (m3/ha) and C stock (tn/ ha) of HWPs in the pilot sites of Thessaloniki and Komotini, Greece for the thinning scenario.

Species	SI	Treatments	Harvested Wood Products (m^3/ha)		Carbon pool (m^3/ha)	C stock (tn C/ha)		
			Wood chips & particles	Wood residues	Oak forest	Wood chips & particles	Wood residues	Oak forest
Pinus halepensis & Pinus brutia	11	1 thinning + final clear cut	60.32	60.32		33	33	
Sum			60.32	60.32		33	33	
Pinus halepensis & Pinus brutia (50%)	15	1 thinning + final clear cut	98.2	98.2		27	27	
Quercus frainetto (50%)	Va	None	-	-	51.42	-	-	24
Sum			98.21	98.21	51.42	27	27	24

The carbon stock of each HWP per pilot site was estimated by multiplying the C stock/ha with the ML area, classified according to method (A, B, C) and type (high or low plantation suitability). The C stock for the pilot sites in Greece are presented in Table 60 and Table 61 for the no thinning scenario, and in Table 62 and Table 63 for the thinning scenario.

Table 60. C stock in the pilot site of Thessaloniki, Greece for the no thinning scenario

			C stock (tn C/ha)			Overall MLs C stock (tn C)		
Method	MLs Type	Area (ha)	Wood chips & particles	Wood residues	Carbon[3] pool	Wood chips & particles	Wood residues	Carbon pool
A	***High plantation suitability***	2,596.9	30	30	24	77.9	77.9	62.8

[3] *Quercus frainetto* forests

	Low plantation suitability	1,887.3	18	18	0	34.0	34.0	0.0
B	*High plantation suitability*	4,377.4	30	30	24	131.3	131.3	105.8
	Low plantation suitability	243.6	18	18	0	4.4	4.4	0.0
C	*High plantation suitability*	4,391.9	30	30	24	131.8	131.8	106.1
	Low plantation suitability	161.5	18	18	0	2.9	2.9	0.0

Table 61. C stock in the pilot site of Komotini, Greece for the no thinning scenario

			C stock (tn C/ha)			**Overall MLs C stock (tn C)**		
Method	**MLs Type**	**Area (ha)**	**Wood chips & particles**	**Wood residues**	**Carbon pool**	**Wood chips & particles**	**Wood residues**	**Carbon pool**
A	*High plantation suitability*	568.9	30	30	24	17.1	17.1	13.7
	Low plantation suitability	1,809.6	18	18	0	32.6	32.6	0.0
B	*High plantation suitability*	2,024.8	30	30	24	60.7	60.7	48.9
	Low plantation suitability	788.7	18	18	0	14.2	14.2	0.0
C	*High plantation suitability*	2,241.5	30	30	24	67.2	67.2	54.2
	Low plantation suitability	572	18	18	0	10.3	10.3	0.0

Table 62. C stock in the pilot site of Thessaloniki, Greece for the thinning scenario

			C stock (tn C/ha)			**Overall MLs C stock (tn C)**		
Method	**MLs Type**	**Area (ha)**	**Wood chips & particles**	**Wood residues**	**Carbon pool**	**Wood chips & particles**	**Wood residues**	**Carbon pool**
A	*High plantation suitability*	2,596.9	27	27	24	70.1	70.1	62.8
	Low plantation suitability	1,887.3	17	17	0	32.1	32.1	0.0
B	*High plantation suitability*	4,377.4	27	27	24	118.2	118.2	105.8
	Low plantation suitability	243.6	17	17	0	4.1	4.1	0.0
C	*High plantation suitability*	4,391.9	27	27	24	118.6	118.6	106.1
	Low plantation suitability	161.5	17	17	0	2.7	2.7	0.0

Table 63. C stock in the pilot site of Komotini, Greece for the thinning scenario

			C stock (tn C/ha)			Overall MLs C stock (tn C)		
Method	**MLs Type**	**Area (ha)**	**Wood chips & particles**	**Wood residues**	**Carbon pool**	**Wood chips & particles**	**Wood residues**	**Carbon pool**
A	***High plantation suitability***	568.9	27	27	24	15.4	15.4	13.7
	Low plantation suitability	1,809.6	17	17	0	30.8	30.8	0.0
B	***High plantation suitability***	2,024.8	27	27	24	54.7	54.7	48.9
	Low plantation suitability	788.7	17	17	0	13.4	13.4	0.0
C	***High plantation suitability***	2,241.5	27	27	24	60.5	60.5	54.2
	Low plantation suitability	572	17	17	0	9.7	9.7	0.0

3.2.7.3 Poland

Based on the ML pilot site the total area of Staszów (Poland) is 4096.4 ha in which 18.9 ha are assigned as Marginal Land 1,1682.5 ha are assigned as Marginal Land 2, and 2394.6 ha are allocated and classified as Unsuitable areas (Table 64).

Table 64. Total Biomass and Carbon stocked for each wood product in each year for the Staszów area.

	ML 1				ML 2			
	Wood Product Biomass (kt)		**Carbon (kt)**		**Wood Product Biomass (kt)**		**Carbon (kt)**	
Year	**Pulp-Fiberboard**	**Sawn wood**	**Pulp-Fiberboard**	**Sawn wood**	**Pulp-Fiberboard**	**Sawn wood**	**Pulp-Fiberboard**	**Sawn wood**
30.00	0.19		0.09	0.00	15.24	0.00	7.50	0.00
50.00	0.41	0.21	0.20	0.10	38.96	19.85	19.18	9.78
Final (100)	0.42	5.78	0.21	2.84	31.70	436.38	15.62	215.06
Total	1.01	5.98	0.50	2.95	85.90	456.23	42.30	224.84

The Marginal Land 1 will have a total of 1.01 kt of Pulp-Fiberboard, where 0.5 kt will be carbon, and a total of 5.98 kt of Sawn Wood, where 2.95 kt will be carbon. The Marginal Land 2 will have a total of 85.90 kt of Pulp-Fiberboard, where 42.30 kt will be carbon stocked, and 456.23 kt of Sawn Wood, where 224.84 will be carbon stocked.

The difference of the total carbon allocated in each area is directly linked to the area of each ML scenario.

3.2.7.4 Spain

The wood products expected to be harvested from the Spanish pilot sites were calculated using the cubiFOR v.2 Tool - Calculation Method, developed by CESEFOR[4]. The calculations are based on the morphological characteristics of the main wood products (crushing, felling, posts, canter, saw and unwinding). The biomass calculations (except for the stem) are based on the equations elaborated by INIA and published by Montero et al. (2005) for each of the biomass products (leaves, branches less than 2 cm, branches 2 to 7 cm, branches greater than 7 cm, stem and roots). For the stem, the calculated volume is used, multiplied by the basic density of the wood.

CubiFOR incorporates equations for *Pinus pinaster, Pinus sylvestris* and *Pinus nigra,* but not *Pinus halepensis.* For the latter, the same equations as for *Pinus pinaster* were used. The detailed results of the CubiFOR analysis for each are shown in Annex IV while the volume and carbon stock per hectare are shown for each pilot site in Table 65 and Table 66. The amount of C stock in the HWPs expected to be produced in the pilot sites was estimated using the CF values included in Table 37.

Table 65.Volume (m3/ha) and C stock (tn/ ha) of HWPs in the pilot sites of Soria and Nogueruelas, Spain.

Species	SI	Treatments	Harvested Wood Products (m^3/ha)			C stock (tn C/ha)		
			Wood chips & particles	Wood based panels	Sawn wood	Wood chips & particles	Wood based panels	Sawn wood
Pinus nigra (80%)	12	3 thinnings + final clear cut	92.6	280.6	0.0	21.2	75.5	0.0
Pinus sylvestris (20%)			16.1	10.0	44.4	3.7	2.7	10.0
Sum			108.7	290.5	44.4	24.9	78.2	10.0
Pinus nigra (80%)	15	3 thinnings +	108.7	122.7	269.4	24.9	33.0	60.6

[4] http://www.cesefor.com/contenido/cubifor-herramienta-descripcion

Pinus sylvestris (20%)		final clear cut	22.3	14.2	59.9	5.1	3.8	13.5
Sum			131.0	136.8	329.3	30.0	36.8	74.1

Table 66. Volume (m3/ha) and C stock (tn/ ha) of HWPs in the pilot site of Espadán, Spain

Species	SI	Treatment	Harvested Wood Products (m^3/ha)			C stock (tn C/ha)		
			Wood chips & particles	Wood based panels	Sawn wood	Wood chips & particles	Wood based panels	Sawn wood
Pinus pinaster (80%)	12	3 thinnings + final clear cut	79.7	30.7	173.8	18.3	8.3	39.1
Pinus halepensis (20%)	11	10 thinnings + final clear cut	12.8	19.8	0.0	2.9	5.3	0.0
Sum			92.5	50.5	173.8	21.2	13.6	39.1
Pinus pinaster (80%)	15	3 thinnings + final clear cut	84.2	80.5	246.8	19.3	21.7	55.5
Pinus halepensis (20%)	14	10 thinnings + final clear cut	14.1	42.7	0.0	3.2	11.5	0.0
Sum			98.4	123.2	246.8	22.5	33.1	55.5

The carbon stock of each HWP per pilot site was estimated by multiplying the C stock/ha with the ML area, classified according to method (A, B, C) and type (high or low plantation suitability). The results are shown in Table 67, Table 68 and Table 69 for each pilot site.

Table 67. C stock per HPW in the pilot site of Nogueruelas, Spain

			C stock (tn C/ha)			Overall MLs C stock (tn C)		
Method	**MLs Type**	**Area (ha)**	**Wood chips & particles**	**Wood based panels**	**Sawn wood**	**Wood chips & particles**	**Wood based panels**	**Sawn wood**
A	***High plantation suitability***	0	30.0	36.8	74.1	0.00	0.00	0.00
	Low plantation suitability	12.7	24.9	78.2	10.0	316.23	992.51	126.87

B	***High plantation suitability***	0.3	30.0	36.8	74.1	9.00	11.04	22.23
	Low plantation suitability	21	24.9	78.2	10.0	522.90	1641.15	209.79
C	***High plantation suitability***	12.7	30.0	36.8	74.1	380.87	467.49	940.94
	Low plantation suitability	8.3	24.9	78.2	10.0	206.67	648.65	82.92

Table 68. C stock per HPW in the pilot site of Soria, Spain

			C stock (tn C/ha)			**Overall MLs C stock (tn C)**		
Method	**MLs Type**	**Area (ha)**	**Wood chips & particles**	**Wood based panels**	**Sawn wood**	**Wood chips & particles**	**Wood based panels**	**Sawn wood**
A	***High plantation suitability***	3611.5	30.0	36.8	74.1	108308.89	132939.32	267576.04
	Low plantation suitability	19194.2	24.9	78.2	10.0	477935.58	1500026.73	191750.06
B	***High plantation suitability***	20367.3	30.0	36.8	74.1	610815.33	749720.31	1509013.26
	Low plantation suitability	5082.2	24.9	78.2	10.0	126546.78	397173.93	50771.18
C	***High plantation suitability***	22587.9	30.0	36.8	74.1	677411.12	831460.60	1673537.51
	Low plantation suitability	2751	24.9	78.2	10.0	68499.90	214990.65	27482.49

Table 69. C stock per HPW in the pilot site of Espadán, Spain

			C stock (tn C/ha)			**Overall MLs C stock (tn C)**		
Method	**MLs Type**	**Area (ha)**	**Wood chips & particles**	**Wood based panels**	**Sawn wood**	**Wood chips & particles**	**Wood based panels**	**Sawn wood**
A	***High plantation suitability***	0	22.5	33.1	55.5	0.00	0.00	0.00
	Low plantation suitability	341.8	21.2	13.6	39.1	7239.32	4645.06	13364.38

B	***High plantation suitability***	103	22.5	33.1	55.5	2320.59	3413.42	5720.62
	Low plantation suitability	272.1	21.2	13.6	39.1	5763.08	3697.84	10639.11
C	***High plantation suitability***	341.2	22.5	33.1	55.5	7687.24	11307.37	18950.25
	Low plantation suitability	33.7	21.2	13.6	39.1	713.77	457.98	1317.67

4. LIFESPAN OF WOOD PRODUCTS FROM MLS

Once the amount of forest products has been calculated, the useful life of these products can be calculated with the equation included in ANNEX III of European Decision 529/2013.

Equation 2. Lifespan and carbon stocked on wood products.

$$C(i+1) = e^{-k} \cdot C(i) + \left[\left(\frac{(1-e^{-k})}{k}\right)\right] \cdot \text{Inflow}(i)$$

$$\Delta C(i) = C(i+1) - C(i)$$

where:

i = year

C(i) = the carbon stock of the harvested wood products pool in the beginning of year i, Gg C

k = decay constant of first-order decay given in units of year^{-1} (k =ln(2)/HL, where HL is half-life of the harvested wood products pool in years.)

Inflow(i) = the inflow to the harvested wood products pool during year i, Gg C year^{-1}

ΔC(i) = carbon stock change of the harvested wood products pool during year i, Gg C year^{-1}

Forest products were classified according to the three categories defined in European Decision 529/2013 and EU Regulation 841/2018. These HWPs were assigned average half-life values, described in section 2.1.1 and below:

(a) 2 years for paper;

(b) 25 years for wood panels;

(c) 35 years for sawn wood.

Emissions from the loss of carbon stored in firewood, wood pellets and wood chips with a short lifespan are normally considered as instantaneous oxidation and not reported as HWP under regulation 841/2018.

Additionally, in the study of half-life values, recycled products can be considered to fine tune the values of half-life wood products.

The forest products will be classified within the 3 categories of woods contemplated by European Decision 529/2013 and these categories will define an average half-life of the product according to the mentioned European Decision:

- Pulp/Fiberboard = 2 years
- SawnWood = 35 Years
- Wood Panels = 25 Years

As the scenario does not imply an inflow of wood products every year, the second part of the equation will be considered equal to zero. Besides that, the ∆C(i) would be related only with the loss of the carbon during the years, since the only increment of carbon that is possible to detect is on the years of interventions and final cut. So, the calculation will be based on the first part of the first equation:

Equation 3. Estimation of carbon stocked on wood products - derived from the Equation 2

$$\underline{C(i + 1) = e^{-k}.C(i)}$$

Besides that, it is also possible to recycle the wood products with the goal to increase the carbon stocked in a specific timeline, based on the research of Navarro et al, 2017 is possible to see the average recycle rate for different wood products, being 70% for paper/fiberboards, 10% for wood panels and 35% for sawn wood. But the study and the influence of recycling is a complex scenario, since in the real world the recycling can lead to a degradation, having products of lower quality and lower life expectancy. Considering that the estimation was carried out just based on the life span of the wood products for each site and no considering any recycle process.

4.1 Germany

For the Welzow area the results are presented on the table below:

Table 70. Lifespan carbon stocked on the wood products in Welzow pilot site area.

	ML1 Welzow Area			ML2 Welzow Area		
Years	Pulp	Sawn Wood	Total (kton)	Pulp	Sawn Wood	Total (kton)
30	1.1000	0.0000	1.1000	2.7600	0.0000	2.7600
40	0.0344	0.0000	0.0344	0.0863	0.0000	0.0863
50	3.6811	3.6000	7.2811	7.9427	7.7700	15.7127
60	0.1150	2.9532	3.0682	0.2482	6.3740	6.6222
70	0.0036	2.4226	2.4262	0.0078	5.2288	5.2366
80	0.0001	1.9874	1.9875	0.0002	4.2894	4.2896
90	0.0000	1.6303	1.6303	0.0000	3.5187	3.5187
100	17.9000	66.3174	84.2174	39.6100	160.0165	199.6265
200	0.0000	9.1525	9.1525	0.0000	22.0841	22.0841
300	0.0000	1.2632	1.2632	0.0000	3.0478	3.0478
400	0.0000	0.1743	0.1743	0.0000	0.4206	0.4206
500	0.0000	0.0241	0.0241	0.0000	0.0581	0.0581
600	0.0000	0.0033	0.0033	0.0000	0.0080	0.0080
700	0.0000	0.0005	0.0005	0.0000	0.0011	0.0011
800	0.0000	0.0001	0.0001	0.0000	0.0002	0.0002
900	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

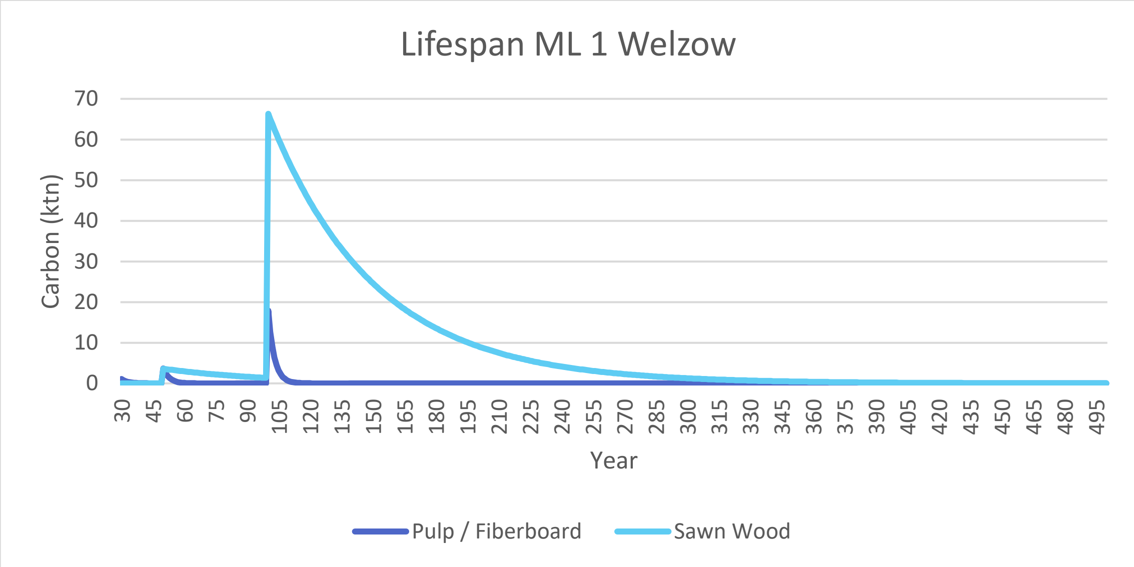


Figure 11. ML1 Germany pilot site Welzow.

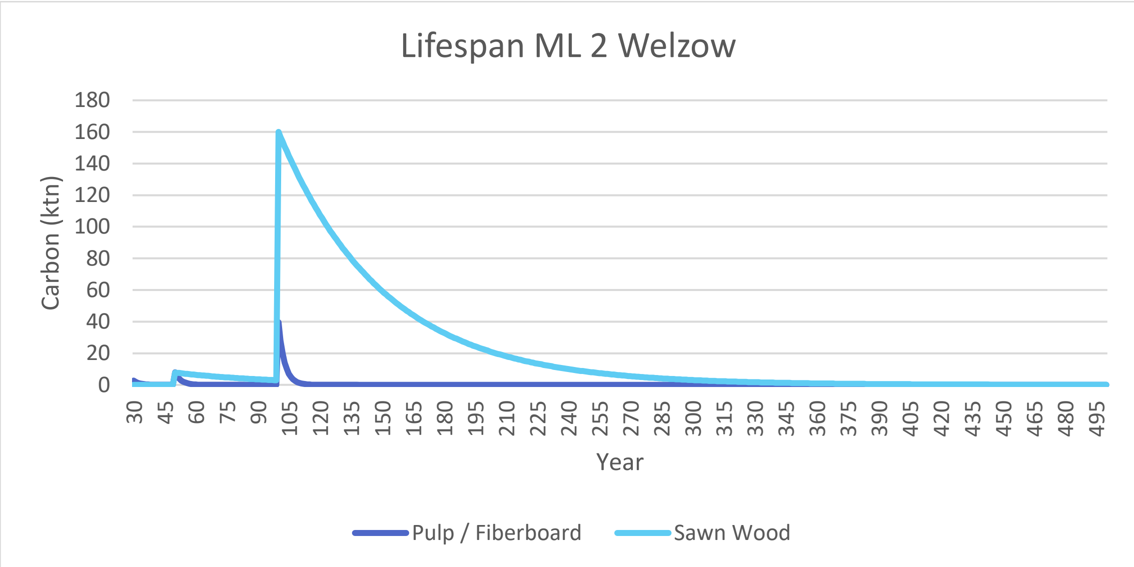


Figure 12. ML2 Germany pilot site Welzow.

As can be seen on the Table 70 for the Welzow area, the wood products from the ML1 will have less than 1ton of carbon stocked after approximately 800 years and having the sawn wood as the main contributor on this, since the lifetime for this is quite larger than the pulp/fiberboard. The peak of the carbon stocked on the wood products will be on the year of the final cut. For the ML2, between the year 800 and 900 the carbon stocked on the wood products will be lower than 1 ton, the peak being on the final harvesting and with the sawn wood as the main contributor to the carbon stocked during the years.

For Notchen area the table are presented below:

Table 71. Lifespan carbon stocked on the wood products in Notchen pilot site area.

	ML1 Notchen Area			ML2 Notchen Area		
Years	**Pulp**	**Sawn Wood**	**Total (kton)**	**Pulp**	**Sawn Wood**	**Total (kton)**
30	1.340	0.000	1.340	2.870	0.000	2.870
40	0.042	0.000	0.042	0.090	0.000	0.090
50	4.501	4.400	8.901	8.253	8.070	16.323
60	0.141	3.609	3.750	0.258	6.620	6.878
70	0.004	2.961	2.965	0.008	5.431	5.439
80	0.000	2.429	2.429	0.000	4.455	4.455
90	0.000	1.993	1.993	0.000	3.655	3.655
100	21.890	81.095	102.985	41.140	166.208	207.348
200	0.000	11.192	11.192	0.000	22.939	22.939
300	0.000	1.545	1.545	0.000	3.166	3.166
400	0.000	0.213	0.213	0.000	0.437	0.437
500	0.000	0.029	0.029	0.000	0.060	0.060
600	0.000	0.004	0.004	0.000	0.008	0.008
700	0.000	0.001	0.001	0.000	0.001	0.001
800	0.000	0.000	0.000	0.000	0.000	0.000
900	0.000	0.000	0.000	0.000	0.000	0.000

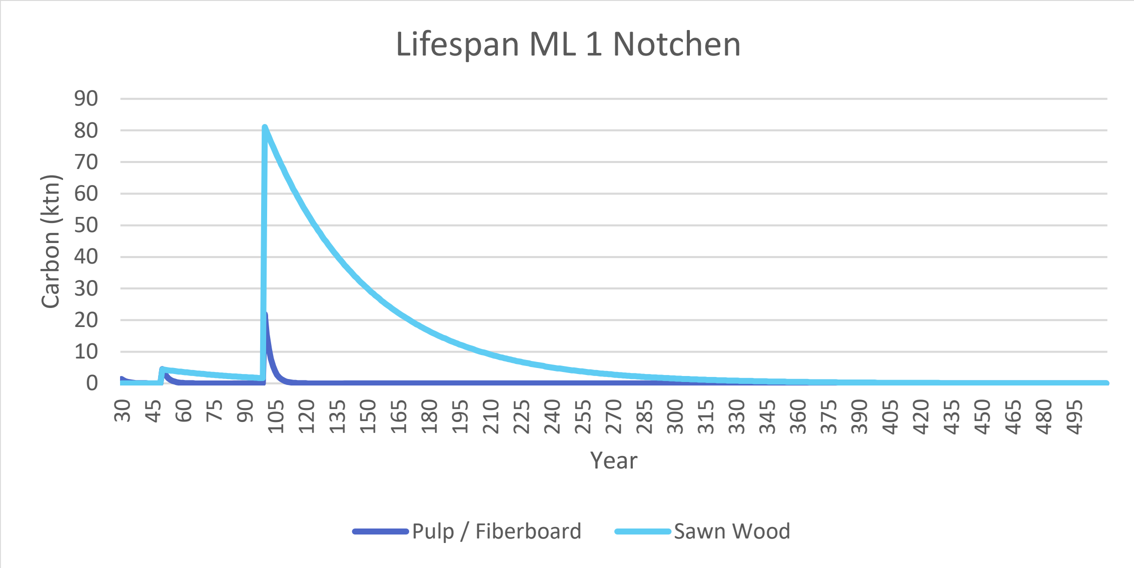


Figure 13. ML1 Germany pilot site Notchen

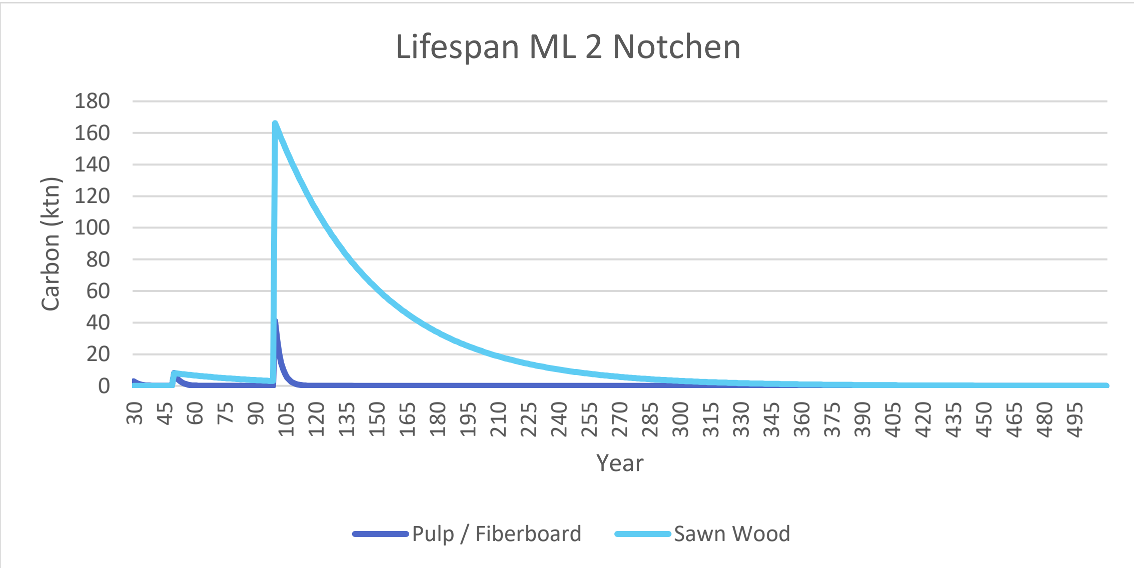


Figure 14. ML2 Germany pilot site Notchen

In Table 71 for the Notchen area, the wood products from the ML1 will have less than 1ton of carbon stocked after approximately 800 years and having the sawn wood as the main contributor on this, since the lifetime for this is quite larger than the pulp/fiberboard. The peak of the carbon stocked on the wood products will be on the year of the final cut. For the ML2, between the year 800 and 900 the carbon stocked on the wood products will be lower than 1 ton, the peak being on the final harvesting and with the sawn wood as the main contributor to the carbon stocked during the years.

As it can be seen the shape of the graphs is similar since the equations are the same for both, just changing the input of carbon in each intervention on the management of the forest.

4.2 Greece

The results of the carbon lifespan analysis in HWP for the Greek pilot sites, under the no thinning scenario, are presented in Table 72:

Table 72. Lifespan of carbon stocked in the wood products of the Greek pilot sites for the no thinning scenario (tn/ha)

Years	Greece ML1 (High plantation suitability)				Greece ML2 (Low plantation suitability)			
	Wood chips - particles	Wood based panels	Sawn wood	Total (tn/ha)	Wood chips - particles	Wood based panels	Sawn wood	Total (tn/ha)
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
65	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	59.8849	0.0	0.0	**59.8849**	36.7050	0.0	0.0	**36.7050**
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
110	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
700	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

The carbon stored in the HWP of the Greek pilot sites will be less than 1ton after approximately 100 years for the MLs with both high (ML1) and low (ML2) plantation suitability since wood chips/ particles have a very short lifespan and are the only HWP. The peak of the carbon stocked in the wood products will be on the year of the final cut for both ML types (Figure 15 and Figure 16).

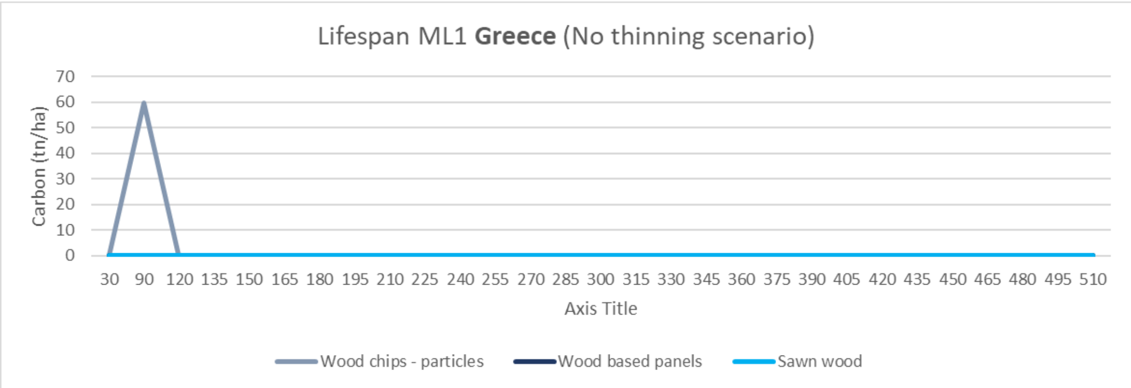


Figure 15. ML1 Greek pilot sites (*P. halepensis & P. brutia*) for the no thinning scenario.

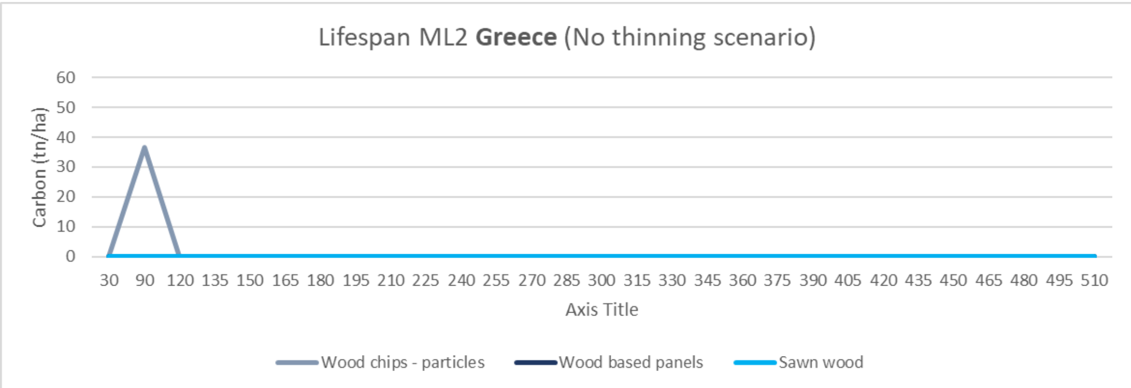


Figure 16. ML2 Greek pilot sites (*P. halepensis & P. brutia*) for the no thinning scenario

The results of the carbon lifespan analysis in HWP for the Greek pilot sites, under the thinning scenario, are presented in Table 73:

Table 73. Lifespan of carbon stocked in the wood products of the Greek pilot sites for the thinning scenario (ktn/ha)

Years	Greece ML1 (High plantation suitability)				Greece ML2 (Low plantation suitability)			
	Wood chips - particles	Wood based panels	Sawn wood	Total (ktn/ha)	Wood chips - particles	Wood based panels	Sawn wood	Total (ktn/ha)
30	0.1199	0.0	0.0	0.1199	0.1439	0.0	0.0	0.1439
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
65	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	53.8964	0.0	0.0	**53.8964**	33.0345	0.0	0.0	**33.0345**
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
110	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
700	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

The carbon stored in the HWP of the Greek pilot sites will be less than 1 ton after approximately 100 years for the MLs with both high (ML1) and low (ML2) plantation suitability since wood chips/ particles have a very short lifespan and are the only HWP. The peak of the carbon stocked in the wood products will be on the year of the final cut for both ML types (Table 17and Table 18).

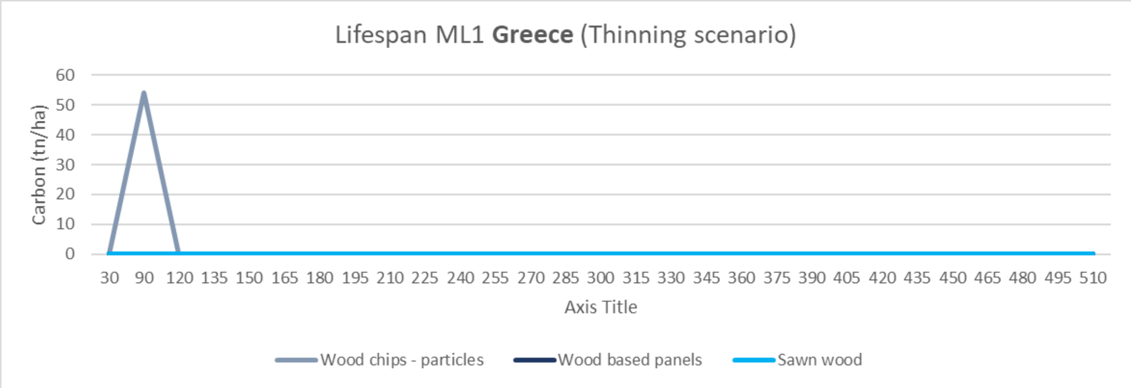


Figure 17. ML1 Greek pilot sites (*P. halepensis & P. brutia*) for the thinning scenario

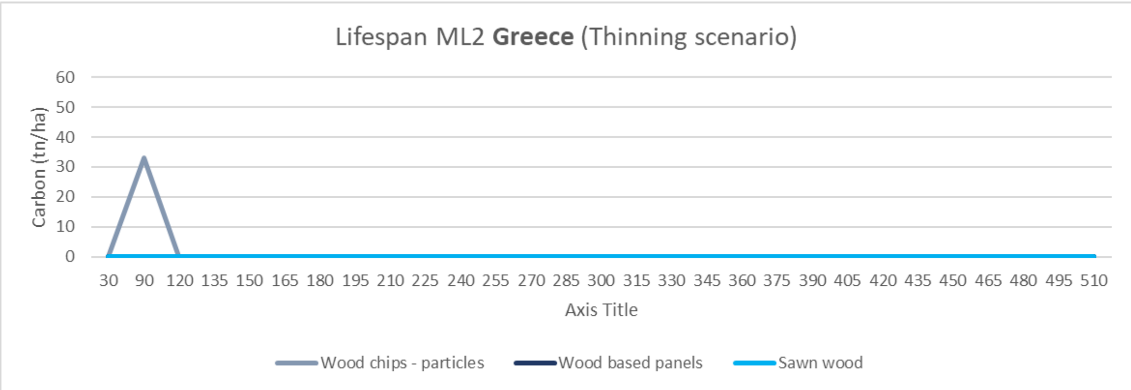


Figure 18.ML2 Greek pilot sites (*P. halepensis & P. brutia*) for the thinning scenario

4.3 Poland

On Table 74 for the Staszów area, is possible to see the wood products on the timeline. Year 0 is considered as the year of the plantation, ML1 will have less than 1ton of carbon stocked after approximately the year 600 and having the sawn wood as the main contributor, since the lifetime for this is quite larger than the pulp/fiberboard.

Table 74. Lifespan carbon stocked in kton on the wood products in Staszów pilot site area.

	Staszów ML1			Staszów ML2		
Years	Pulp	Sawn	Total (kton)	Pulp	Sawn	Total (kton)
30	0.0900	0.0	0.0900	7.5000	0.0	7.5000
40	0.0028	0.0	0.0028	0.2344	0.0	0.2344

50	0.2001	0.1000	0.3001	19.1873	9.7800	28.9673
60	0.0063	0.0820	0.0883	0.5996	8.0229	8.6225
70	0.0002	0.0673	0.0675	0.0187	6.5815	6.6002
80	0.0	0.0552	0.0552	0.0006	5.3990	5.3996
90	0.0	0.0453	0.0453	0.0	4.4290	4.4290
100	0.2100	2.8771	3.0871	15.6200	218.6933	234.3133
200	0.0	0.3971	0.3971	0.0	30.1821	30.1821
300	0.0	0.0548	0.0548	0.0	4.1655	4.1655
400	0.0	0.0076	0.0076	0.0	0.5749	0.5749
500	0.0	0.0010	0.0010	0.0	0.0793	0.0793
600	0.0	0.0001	0.0001	0.0	0.0109	0.0109
700	0.0	0.0	0.0	0.0	0.0015	0.0015
800	0.0	0.0	0.0	0.0	0.0002	0.0002
900	0.0	0.0	0.0	0.0	0.0	0.0

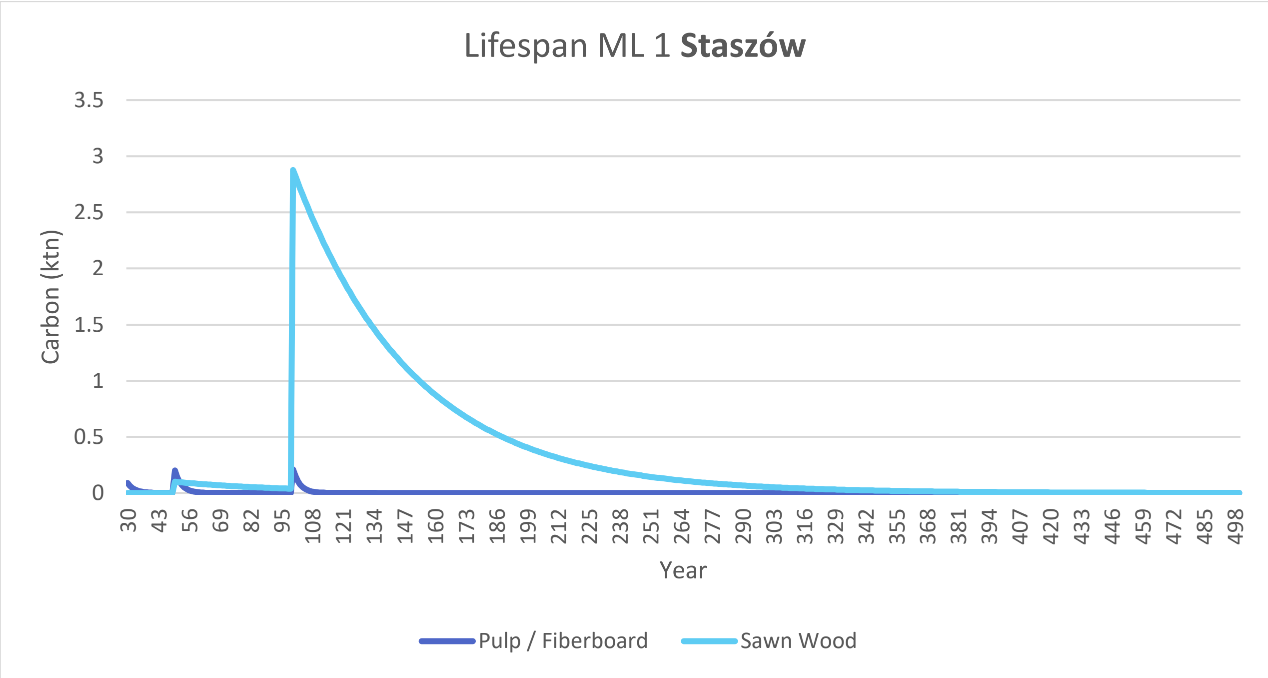


Figure 19. Lifespan of carbon stocked on wood products of the Marginal Land 01 on the Staszów area.

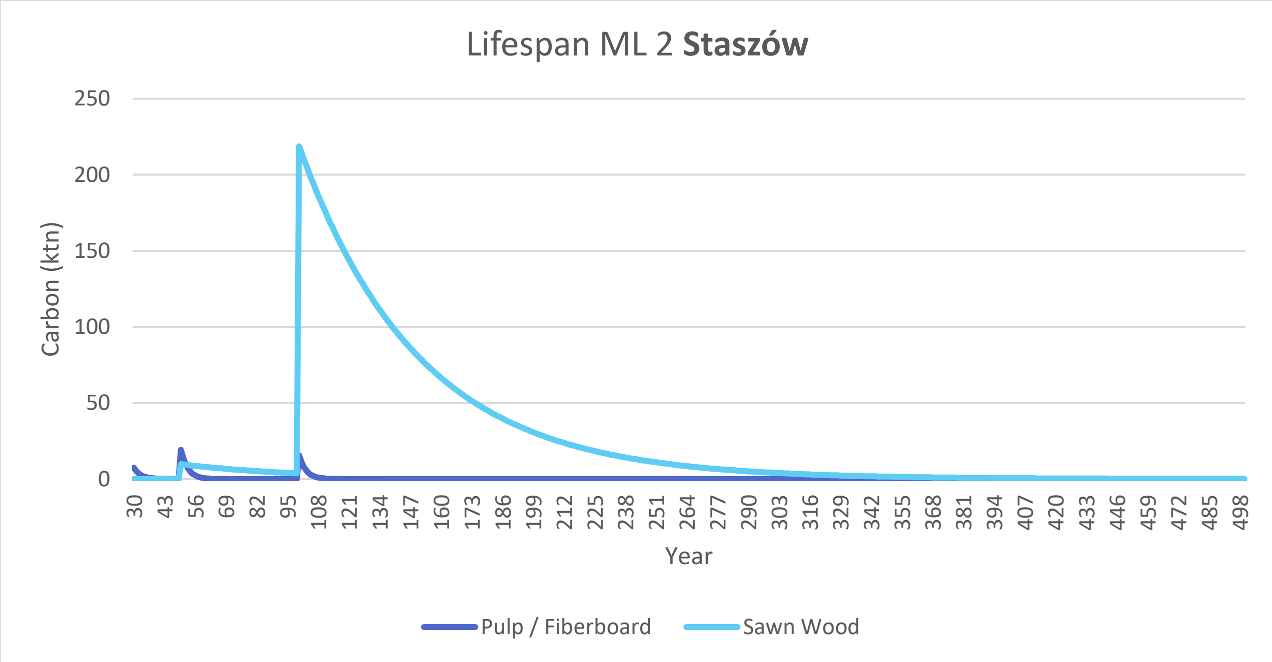


Figure 20. Lifespan of carbon stocked on wood products of the Marginal Land 02 on the Staszów area.

The peak of the carbon stocked on the wood products will be on the year of the final cut. For the ML2, between the year 800 and 900 the carbon stocked on the wood products will be lower than 1 ton, the peak being on the final harvesting and with the sawn wood as the main contributor to the carbon stocked during the years. The shape of the graphs will be similar. It is important to take into account the Y axis which is quite different since the ML2 has a higher area and as consequence more carbon per ha, and also with almost 200 years more permanence of the carbon on the wood products.

Another interesting and important point is that after the year 100, new plantations can be carried out, so the area will have new inflow of wood products.

4.4 Spain

The results of the carbon lifespan analysis in HWP for the Espadan pilot site are presented in Table 75:

Table 75. Lifespan of carbon stocked in the wood products of the Espadan pilot site (ktn/ha)

Years	Espadan ML1 (High plantation suitability)				Espadan ML2 (Low plantation suitability)			
	Wood chips - particles	Wood based panels	Sawn wood	Total (tn/ha)	Wood chips - particles	Wood based panels	Sawn wood	Total (tn/ha)
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	9.1600	0.0	0.0	9.1600	0.0	0.0	0.0	0.0
40	1.3942	0.0	0.0	1.3942	7.4708	0.0	0.0	7.4708
45	8.8942	0.0	0.0	8.8942	0.0	0.0	0.0	0.0
50	0.2689	0.0	0.0	0.2689	11.1462	0.0	0.0	11.1462
60	4.8203	14.3232	0.0	19.1435	0.9655	0.0	0.0	0.9655
65	0.0	12.4691	0.0	12.4691	1.2038	7.2159	0.0	8.4197
70	2.3465	10.8549	0.0	13.2015	0.8497	6.2818	0.0	7.1315
75	3.6803	9.4498	69.4210	82.5511	0.0	5.4687	0.0	5.4687
80	1.9936	8.2265	62.8763	73.0964	4.0532	4.7607	48.8773	57.6912
90	1.7767	6.2345	51.5796	59.5909	0.7939	3.6080	40.0958	44.4977
100	0.9813	5.0865	42.3126	48.3804	0.6662	2.7343	32.8920	36.2925
110	0.8181	4.2467	34.7105	39.7753	0.5640	2.0722	26.9824	29.6187
120	4.1664	59.5839	28.4743	**92.2245**	9.7252	28.2570	22.1347	**60.1169**
200	0.0	6.4838	5.8396	12.3235	0.0	3.0749	4.5395	7.6144
300	0.0	0.4052	0.8059	1.2112	0.0	0.1922	0.6265	0.8187
400	0.0	0.0253	0.1112	0.1366	0.0	0.0120	0.0865	0.0985
500	0.0	0.0015	0.0154	0.0169	0.0	0.0008	0.0119	0.0127
600	0.0	0.0	0.0021	0.0021	0.0	0.0	0.0016	0.0016
700	0.0	0.0	0.0003	0.0003	0.0	0.0	0.0002	0.0002
800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

The carbon stored in the HWP of the Espadan pilot site will be less than 1ton after approximately 400 years for the MLs with high plantation suitability sites (ML1), having the sawn wood as the main contributor on this, since the lifetime for this is quite larger than the wood chips/ particles. The peak of the carbon stocked in the wood products will be on the year of the final cut (Figure 21). For the low plantation suitability sites (ML2), the carbon stocked on the wood products will be lower than 1 ton between the years 200 and 300. The peak will be on the final harvesting, with sawn wood as the main contributor to the carbon stocked during the years, same as for ML1 (Figure 22).

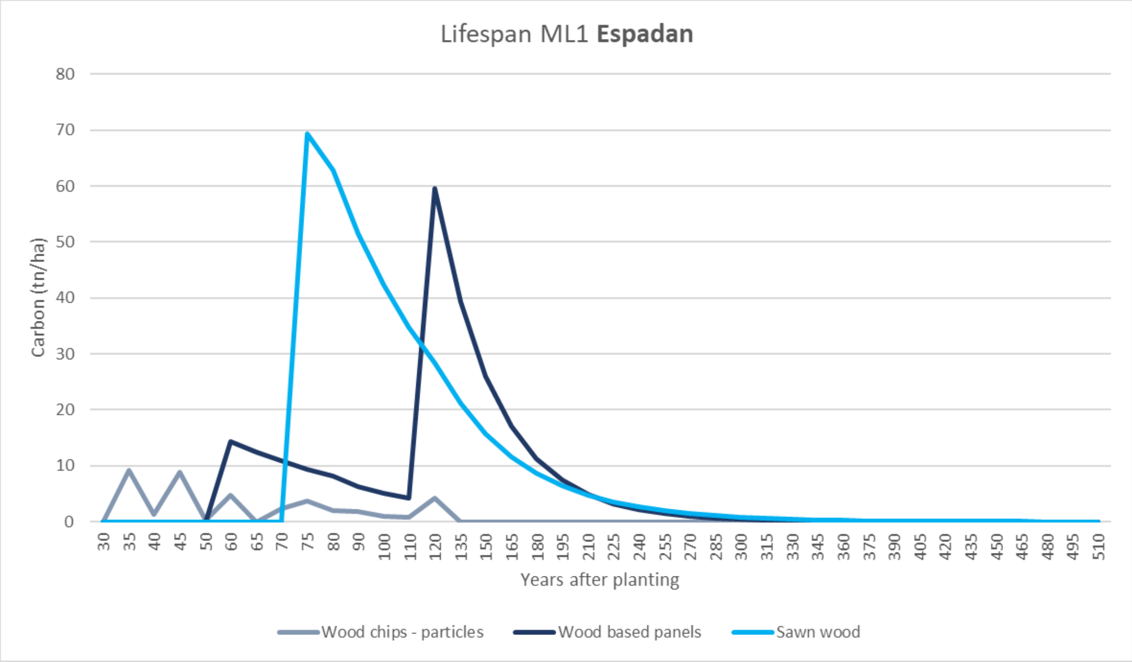


Figure 21.ML1 Pilot site Espadan (*P. pinaster & P. halepensis*)

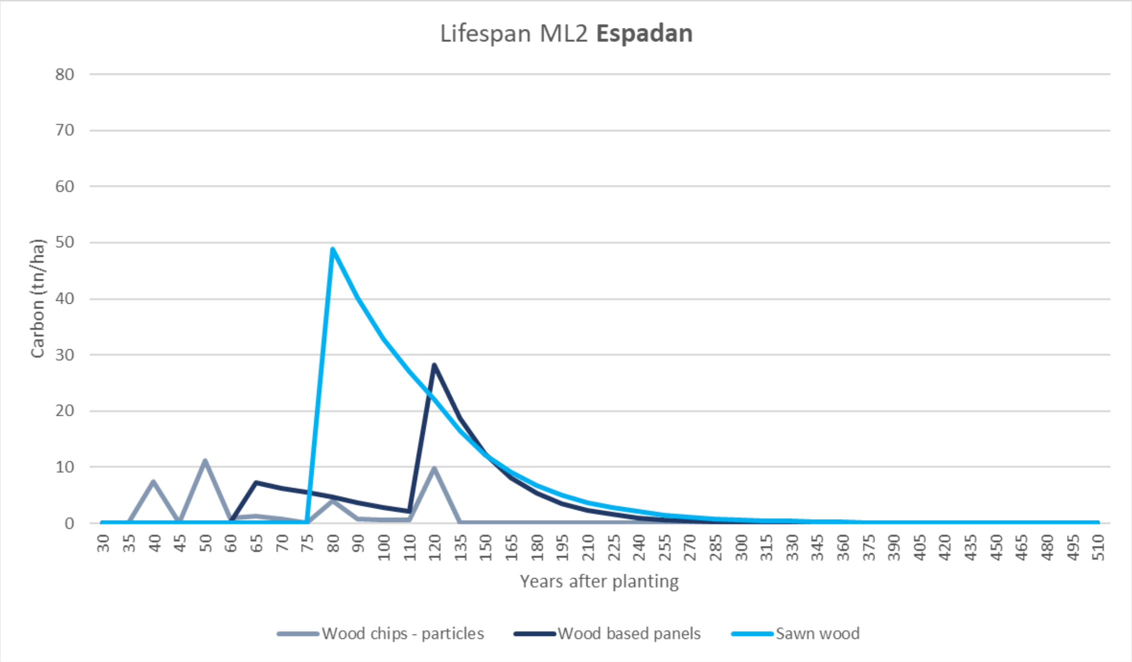


Figure 22. ML2 Pilot site Espadan *(P. pinaster & P. halepensis*)

The results of the carbon lifespan analysis in HWP for the Soria and Nogueruelas pilot sites are presented in Table 76:

Table 76. Lifespan of carbon stocked in the wood products of the Soria and Nogueruelas pilot sites (ktn/ha)

Years	Soria & Nogueruelas ML1 (High plantation suitability)				Soria & Nogueruelas ML2 (Low plantation suitability)			
	Wood chips - particles	Wood based panels	Sawn wood	Total (tn/ha)	Wood chips - particles	Wood based panels	Sawn wood	Total (tn/ha)
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	7.7077	0.0	0.0	7.7077	0.0	0.0	0.0	0.0
40	16.0047	0.0	0.0	16.0047	6.1592	0.0	0.0	6.1592
45	0.0	0.0	0.0	0.0	9.9002	0.0	0.0	9.9002
50	8.5482	0.0	0.0	8.5482	0.0	0.0	0.0	0.0
55	0.0	10.1636	0.0	10.1636	6.2113	0.0	0.0	6.2113
60	0.0	8.8479	0.0	8.8479	6.1209	5.8525	0.0	11.9734
65	2.9676	7.7026	0.0	10.6702	0.0	5.0949	0.0	5.0949
70	4.6090	23.4424	0.0	28.0514	2.7397	4.4354	0.0	7.1751
75	0.0	20.4078	0.0	20.4078	4.9252	15.7717	0.0	20.6969
80	5.3811	17.7660	75.7657	98.9128	0.0	13.7301	0.0	13.7301
85	0.0	15.4662	68.6228	84.0890	5.5741	79.6955	0.0	85.2695
90	0.0	10.2039	50.9865	61.1904	0.0	52.5794	0.0	52.5794
110	6.2660	7.7331	109.2348	**123.2339**	3.2690	39.8477	49.9590	**93.0758**
120	0.0	5.8606	89.6092	95.4698	0.0	30.1989	40.9831	71.1821
200	0.0	0.6377	18.3774	19.0151	0.0	3.2862	8.4050	11.6912
300	0.0	0.0399	2.5363	2.5761	0.0	0.2054	1.1600	1.3654
400	0.0	0.0025	0.3500	0.3525	0.0	0.0128	0.1601	0.1729
500	0.0	0.0001	0.0483	0.0484	0.0	0.0008	0.0221	0.0229
600	0.0	0.0	0.0067	0.0067	0.0	0.0001	0.0030	0.0031
700	0.0	0.0	0.0009	0.0009	0.0	0.0	0.0004	0.0004
800	0.0	0.0	0.0001	0.0001	0.0	0.0	0.0001	0.0001
900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

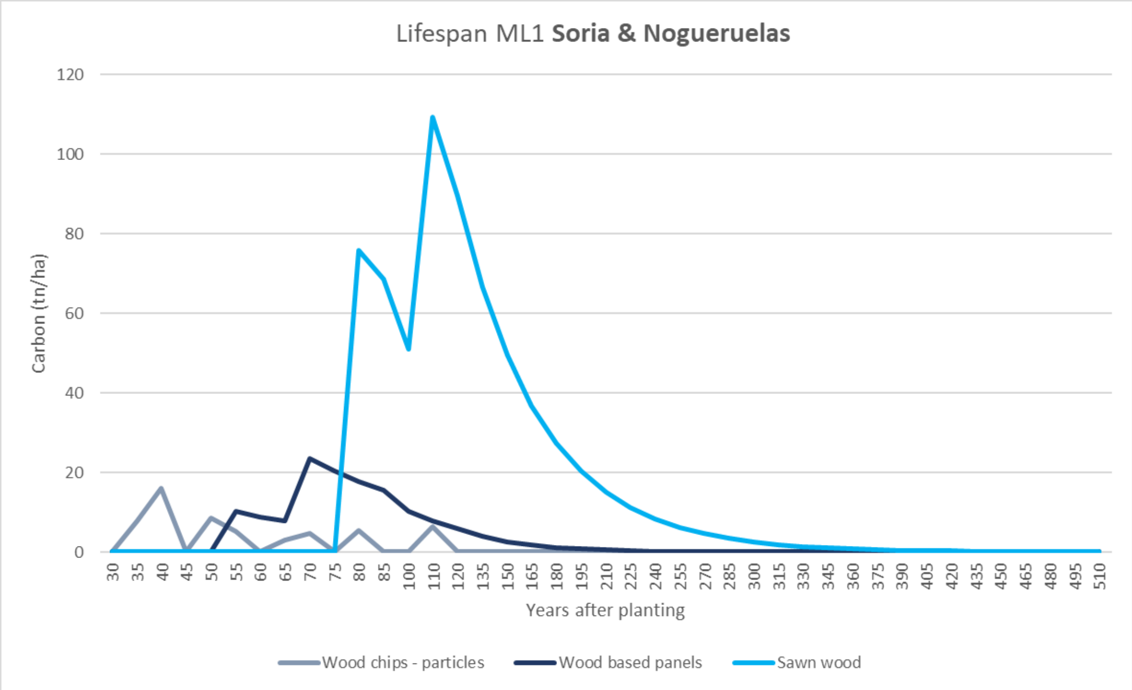


Figure 23. ML1 Pilot sites Soria and Nogueruelas (*P. nigra & P. sylvestris*)

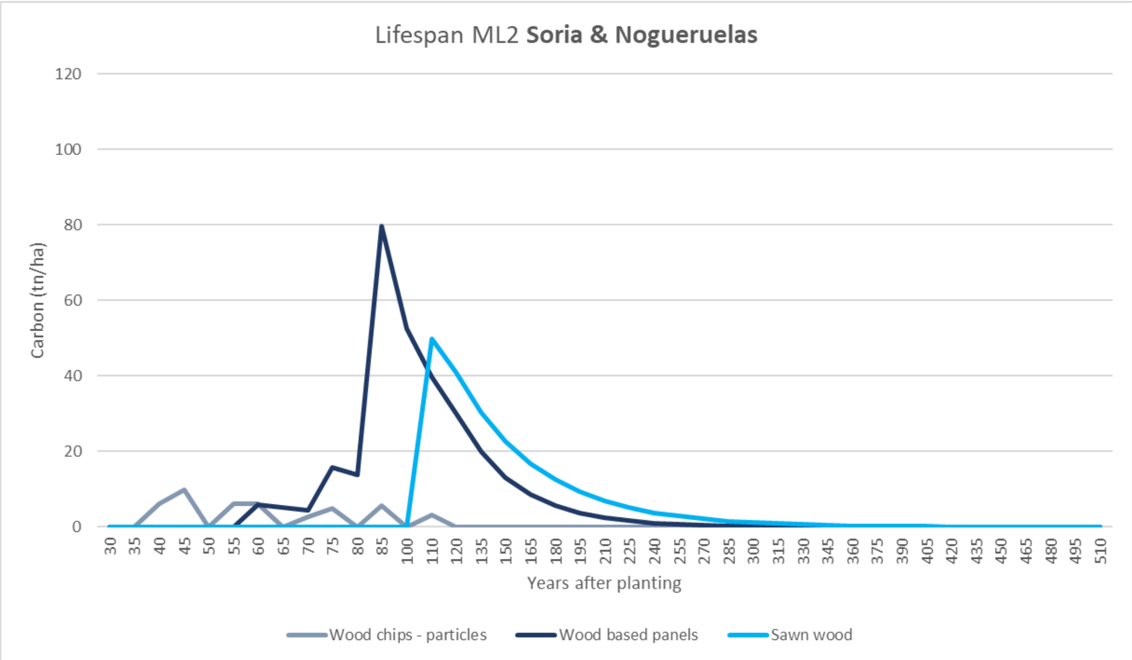


Figure 24. ML2 Pilot sites Soria and Nogueruelas (*P. nigra & P. sylvestris*)

5. MARKET STUDY IN PRIMARY WOOD-PROCESSING INDUSTRIES

5.1 General picture of European statistics

In terms of the area covered by forests in Europe, in 2019, the EU-27 had an estimated 159 million hectares of forests (excluding other wooded land) and their area was increased by almost 10 % since 1990. Forest area was increased in all EU-27 countries with the exception of Slovenia and Sweden, where a small decrease by <0.5 % was reported, and Portugal, where forest area decreased by 3 % in the period of 1990–2019. The largest increase took place in Ireland (69 %), Spain (34 %) and Malta (31%); however, in two of these countries forest covers only a small share of land.

The percentage of land area covered by forests in 2019, as shown in the picture below, presents some interesting outputs; although the area covered by forests follows an order of priority with ***MAIL*** countries Spain (37%), Germany (32%), Poland & Greece (30%), this is not in line with the annual production of roundwood of these countries, as Germany comes first followed by Poland, Spain and Greece.

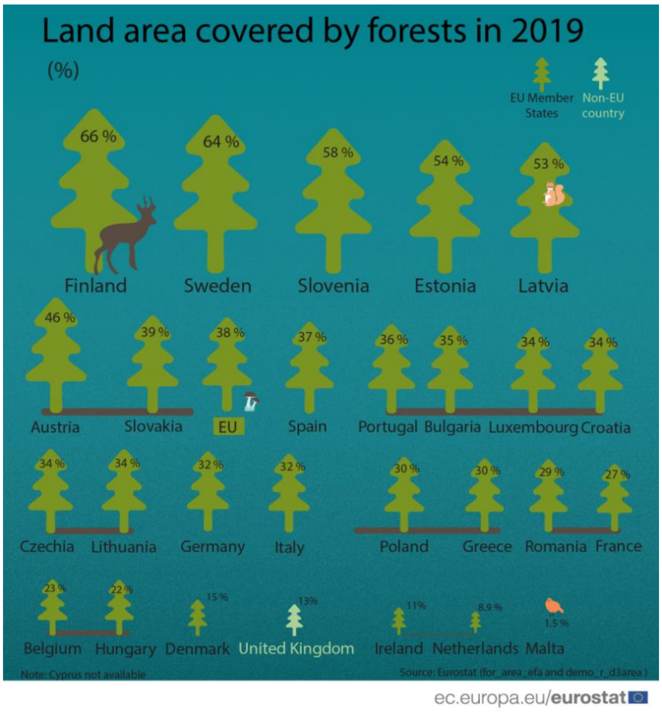


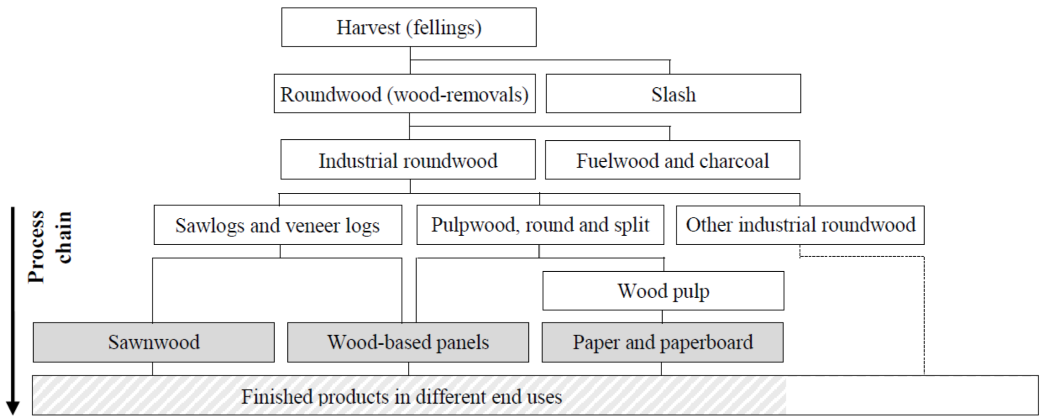
Figure 25.Land area covered by forests in 2019 (Source: Eurostat)

In Table 77 the changes in the area of forest land for each country of the ***MAIL*** project are presented at given reference time periods for the 30-year period when the market study has been retrieving data. This information has been used in order to calculate the mean production of wood products per ha of forest land for each pilot country so that the dynamics of forest land changes do not become disregarded.

Table 77.Change in ha of forest land per pilot country of MAIL project (source FOREST EUROPE, 2020: State of Europe's Forests 2020. UNECE, FAO)

Pilot country	Time of reference		
	2000	**2010**	**2020**
Germany	11,354	11,409	11,419
Greece	3,601	3,903	3,903
Poland	9,059	9,329	9,483
Spain	17,094	18,545	18,572

The forest-wood chain starts with "forest harvesting" (or "fellings"). Forest harvesting is then partitioned into "roundwood" (or "wood-removals") and "slash" (generally left in the forest). Roundwood is then further subdivided into "industrial roundwood" and types of fuelwood and charcoal. Following the forest products definitions of the FAO, in the figure below, the relationship between the aggregate commodity "industrial roundwood" and the three semi-finished wood product commodity classes is shown.



Source: IPCC 2014

Figure 26. Simplified classification of wood products based on FAO forest products definitions (source IPCC, 2019)

Overall roundwood production at EU-28 level reached an estimated 425 million m^3 in 2014, some 37 million m^3 (8 %) less than the peak output level recorded in 2007. Some of the peaks (most recently 2000, 2005 and 2007) in roundwood production were due to forestry and logging having to cope with unplanned numbers of trees that fell by severe storms.

From 2000 to 2007, there was a steady increase in the level of roundwood production in the EU-28. While the output of non-coniferous (broadleaved or hardwood) species remained relatively stable, there were greater year-on-year differences for coniferous (softwood) species (see Figure 26). The effects of the financial and economic crisis led to a drop of the level of EU-28 coniferous production in 2008, a pattern confirmed by a further reduction in 2009. The output has since returned to pre-crisis levels of approximately 280 million m^3 per annum.

Traditionally, the output of roundwood in the EU has been dominated by coniferous trees. In 2019, coniferous trees accounted for 69 % of all roundwood harvested in the forests of EU-27 countries which is the same relative proportion as in year 2000 and, overall, this share has remained stable throughout 2000–2019 (Figure 27). Non-coniferous production increased relative to coniferous production ever since the crisis years. In 2010, EU-28 total roundwood production rebounded strongly by 10 % and continued to rise in 2011, levelled out in 2012 and 2013, and decreased by –2 % in 2014.

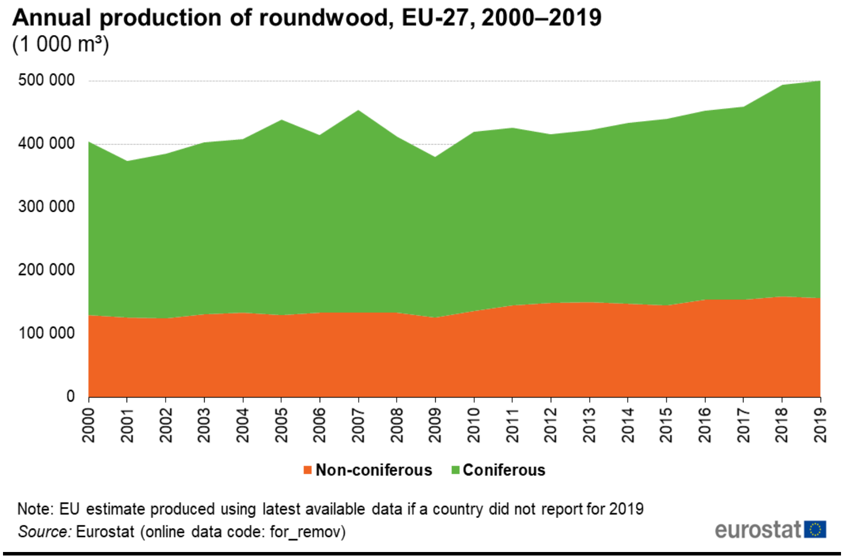


Figure 27. Annual production of roundwood, EU-28, 1995–2014 (1) (million m3) Source: Eurostat.

A range of economic indicators for forestry and logging activities are presented across EU Member States in Figure 28. The economic importance of an industry can be measured by the share of its gross value added (GVA) in the economy. The data come from European Forest Accounts – a data collection of Eurostat on forests, forestry and logging industry.

The EU's wood-based industries cover a range of downstream activities, including woodworking industries, large parts of the furniture industry, pulp and paper manufacturing and converting industries, and the printing industry. Together, some 397,000 enterprises were active in wood-based industries across the EU-27 in 2018; they represented one in five (19.6 %) manufacturing enterprises across the EU-27, highlighting that - with the exception of pulp and paper manufacturing that is characterized by economies of scale - many wood-based industries had a relatively high number of small or medium-sized enterprises.

Total gross value added (GVA) generated by forestry and logging industry in EU-27 was EUR 26.7 billion in 2018. In absolute terms, these industries generated the greatest GVA in Finland, France, Germany and Sweden among EU Member States in 2018 – more than EUR 3 billion in each of them (please note that values are shown in current prices).

Gross value added of forestry and logging industry represented 0.2 % of the GDP of EU-27 in 2018, i.e. it accounted for an equal share of GDP as in 2000. The economic importance of forestry and logging, expressed as the share of GVA generated by the industry in the total GDP of the country, was greatest in Latvia and Finland where it reached 1.9 % and 1.8 % GDP respectively and showed an increase compared to 2000 in both countries.

On average, forests of EU-27 countries generated 168 EUR/ha of GVA in 2018. The largest GVA per forest area was generated in Denmark, Czechia, and the Netherlands in 2018. While this indicator may be affected by the type of activities performed by the forestry and logging sector, it may be used as a proxy of economic productivity of forestry activities across the EU.

The largest forestry and logging activities on the basis of gross value added generated in 2018 were found in Finland, Sweden, France and Germany.

	Gross value added		Gross value added/forest area		Gross value added as a % of GDP	
	(million EUR)		(EUR / hectare)		(%)	
	2000	2018	2000	2018	2000	2018
EU-27	16.669	26 674	110	168	0,2	0,2
Belgium	100	84	149	121	0,0	0,0
Bulgaria	52	263	15	68	0,4	0,5
Czechia	388	1 182	147	442	0,6	0,6
Denmark	129	349	226	557	0,1	0,1
Germany	1 601	3 143	141	275	0,1	0,1
Estonia	69	238	31	98	1,1	0,9
Ireland	53	19	84	24	0,0	0,0
Greece	64	56	18	14	0,0	0,0
Spain	1.448	1 010	85	54	0,2	0,1
France	2 674	3 523	175	206	0,2	0,1
Croatia	106	216	56	112	0,5	0,4
Italy	1.083	1 971	129	208	0,1	0,1
Cyprus	:	2	:	:		0,0
Latvia	123	555	38	163	1,4	1,9
Lithuania	65	268	32	122	0,5	0,6
Luxembourg	12	35	140	400	0,1	0,1
Hungary	143	264	74	129	0,3	0,2
Malta	0	0	:	:	0,0	0,0
Netherlands	76	158	211	430	0,0	0,0
Austria	861	1 066	224	274	0,4	0,3
Poland	705	1 561	78	165	0,4	0,3
Portugal	1.253	952	382	288	1,0	0,5
Romania	193	1.780	30	257	0,5	0,9
Slovenia	93	283	75	228	0,4	0,6
Slovakia	129	494	68	256	0,6	0,6
Finland	2 239	4 111	100	183	1,6	1,8
Sweden	3.013	3.089	107	110	1,1	0,7
United Kingdom	:	612	:	193		0,0
Norway	:	690	:	57		0,2
Switzerland	195	358	163	284	0,1	0,1

(:) not available

Source: Eurostat (online data codes: for_eco_cp, for_area_efa and nama_10_gdp)

Figure 28. Gross value added, gross value added per forest area and gross value added as a percentage of GDP.

Forestry and logging gross value added per area of forest has been substantially raised in the period 2000-2018 in Germany followed by Poland and Spain, whereas Greece does not present any significant increase.

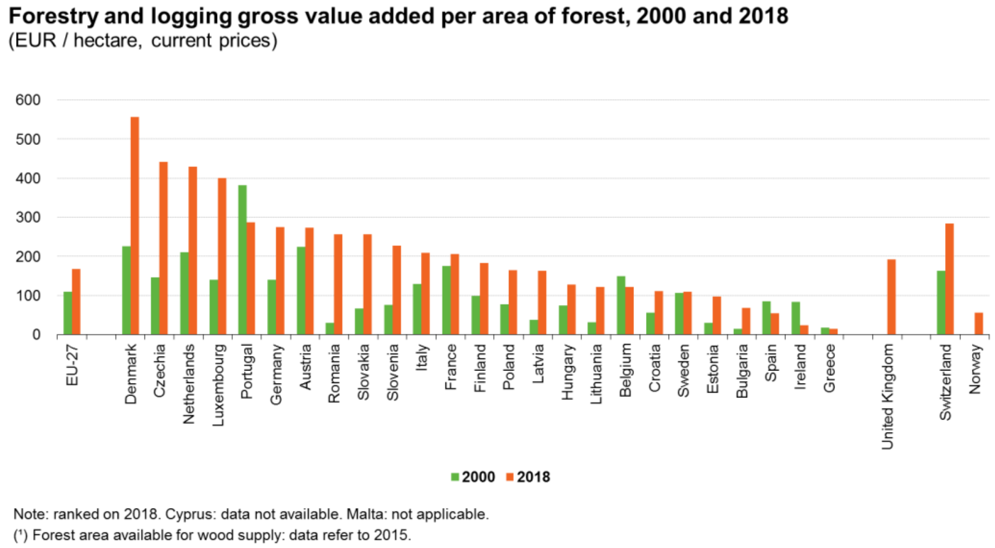


Figure 29. Forestry and logging gross value added per area of forest, 2000 and 2018 (Source, Eurostat)

Wood has been increasingly used as a source of renewable energy. Almost a quarter (23 %) of the EU-27's roundwood production in 2019 was used as fuelwood, while the remainder was industrial roundwood used for sawnwood and veneers, or for pulp and paper production. This represents an increase of 6 percentage points compared to 2000, when fuelwood accounted for 17 % of the total roundwood production. In some Member States, specifically Cyprus, the Netherlands and Italy, fuelwood represented the majority of roundwood production (more than 60 %) in 2019. On the other hand, Ireland, Slovakia, and Sweden reported that over 90 % of their total roundwood production was industrial roundwood. While the share of fuelwood in roundwood production differs across EU-27 countries, most Member States reported its increase since 2000. The largest increase was recorded for the Netherlands (58 %) and Cyprus (52 %) as shown in Figure 29. The share in fuelwood in total roundwood production has had a significant increase in Germany for the period 2000-2019, while for Spain and Poland changes are really small.

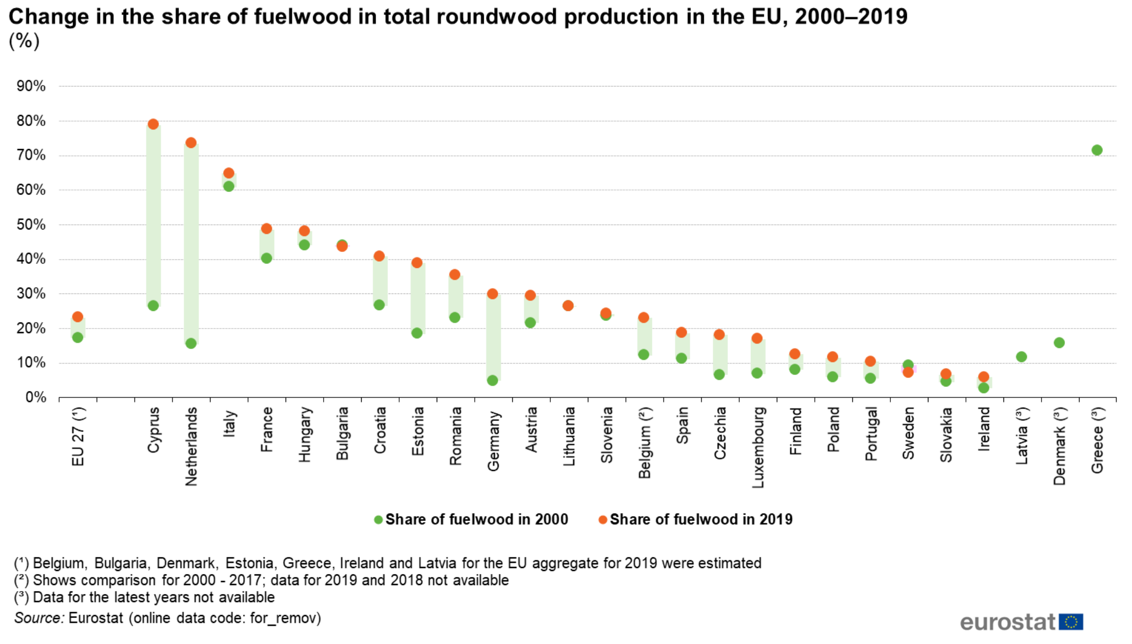


Figure 30. Change in the share of fuelwood in total roundwood production in the EU.(Source: Eurosat)

5.2 Production of wood product categories per pilot country

5.2.1 Germany

- Production of wood product categories (in total)

Germany holds the largest part in the production of wood and wood products industry among all four pilot countries of the ***MAIL*** project considering the mean production of roundwood per ha of forest land. Wood production of roundwood in Germany has been heading at the industrial roundwood processing, which shows a declining representation in favor of increasing trends in the use of wood fuel (Table 78, Table 79).

Table 78. Production (in million cubic meters) and participation (in %) of industrial roundwood & wood fuel in the roundwood production for the period 1990-2019 in Germany (source FAOSTAT-Forestry database)

Production per wood product category	Unit	Time period		
		1990-1999	2000-2009	2010-2019
Roundwood	($10^6 m^3$)	466.42	595.36	718.81

Industrial roundwood	(10^6m^3)	406.49	446.53	472.25
	%	*87.15*	*75.00*	*65.70*
Wood fuel	(10^6m^3)	59.94	148.83	246.56
	%	*12.85*	*25.00*	*34.30*

Table 79. Production (in million cubic meters) of the three semi-finished wood product commodity classes for the period 1990-2019 in Germany (source FAOSTAT-Forestry database)

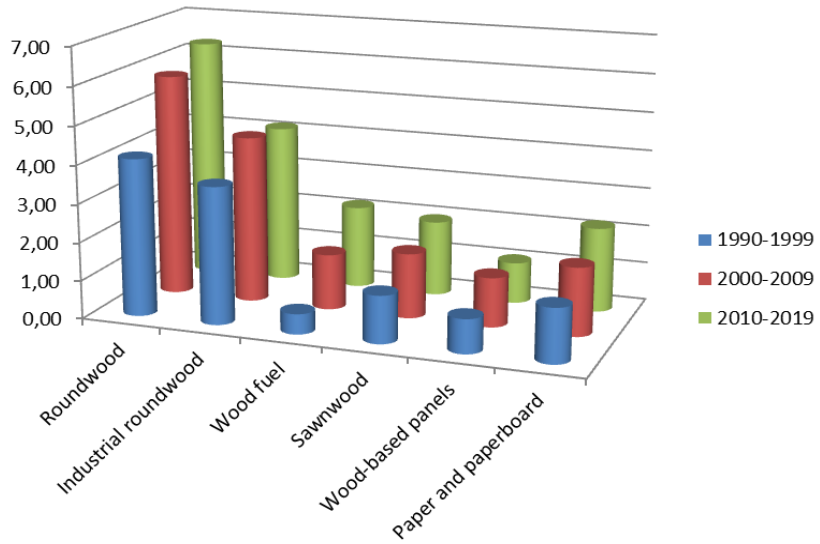
Production per wood product category	Unit	Time period		
		1990-1999	2000-2009	2010-2019
Sawnwood	(10^6m^3)	140.8	173.69	224.22
Wood-based panels	(10^6m^3)	100.89	132.35	122.06
Paper and paperboard	(tn)	144.35	182.98	226.23
	(10^6m^3)	160.38	203.31	251.37

- <u>Mean production of wood product per ha of forest land</u>

Mean production of wood products per ha of forest land in Germany has been increasing over the past 30 years, with exception of wood-based panels (Table 80).

Table 80. Mean production of wood products per ha of forest land in Germany considering forest land changes per time period (source FAOSTAT-Forestry database)

Mean production of wood products per ha of forest land (10^6m^3/ha)	Time period		
	1990-1999	2000-2009	2010-2019
Roundwood	4.11	5.80	6.29
Industrial roundwood	3.58	4.35	4.14
Wood fuel	0.53	1.45	2.16
Sawnwood	1.24	1.69	1.96
Wood-based panels	0.89	1.29	1.07
Paper and paperboard	1.41	1.78	2.20



5.2.2 Greece

- Production of forest product categories (in total)

During the last decade, the Greek wood fuel market has been expanding, with participation of wood fuel production being almost twice greater in comparison with that of industrial roundwood. This trend is holding steady even if roundwood production has been decreasing over the last 30 years in Greece. The fuel wood production has strengthened the Greek wood market and economy with the utilization of fuel wood for industrial purposes being much smaller than household utilization, mainly due to the increased demand amid the economic recession of the last decade.

The long-length roundwood constitutes the most important product of Greek forests as is of high added value and in its processing form (sawn wood, veneer, fibreboards, particleboards) it has a lot of uses in the building activity, constructions and furniture and is considered as the most important for the economy of a country. The main source of long-length roundwood are species like fir and spruce, pine, beech, oak and poplar and other broadleaved (Table 81, Table 82).

Table 81. Production (in million cubic meters) and participation (in %) of industrial roundwood & wood fuel in the roundwood production for the period 1990-2019 in Greece (source FAOSTAT-Forestry database)

Production per wood product category	Unit	Time period		
		1990-1999	2000-2009	2010-2019
Roundwood	($10^6 m^3$)	21.29	15.16	14.28
Industrial roundwood	($10^6 m^3$)	7.58	5.43	4.47
	%	*35.60*	*35.82*	*31.30*
Wood fuel	($10^6 m^3$)	13.71	9.73	9.81
	%	*64.40*	*64.18*	*68.70*

Table 82. Production (in million cubic meters) of the three semi-finished wood product commodity classes for the period 1990-2019 in Greece (source FAOSTAT-Forestry database)

Production per wood product category	Unit	Time period		
		1990-1999	2000-2009	2010-2019
Sawnwood	($10^6 m^3$)	2.83	1.34	0.95
Wood-based panels	($10^6 m^3$)	3.61	7.12	4.83
Paper and paperboard	(tn)	5.78	4.34	4.10
	($10^6 m^3$)	6.42	4.82	4.56

- <u>Mean production of wood products per ha of forest land</u>

Mean production of wood products per ha of forest land in Greece shows a large representation of wood fuel in the destination of the harvested wood. Also, destination of industrial roundwood to sawnwood is very small, explaining the low importance of the Greek sawnwood in the wood market, with most of best quality sawnwood being imported (Table 83).

Table 83. Mean production of wood products per ha of forest land in Greece considering forest land changes per time period (source FAOSTAT-Forestry database)

Mean production of wood	Time period

products per ha of forest land ($10^6 m^3/ha$)	1990-1999	2000-2009	2010-2019
Roundwood	0.59	0.43	0.37
Industrial roundwood	0.21	0.15	0.11
Wood fuel	0.38	0.28	0.25
Sawnwood	0.08	0.04	0.02
Wood-based panels	0.10	0.20	0.12
Paper and paperboard	0.18	0.12	0.12

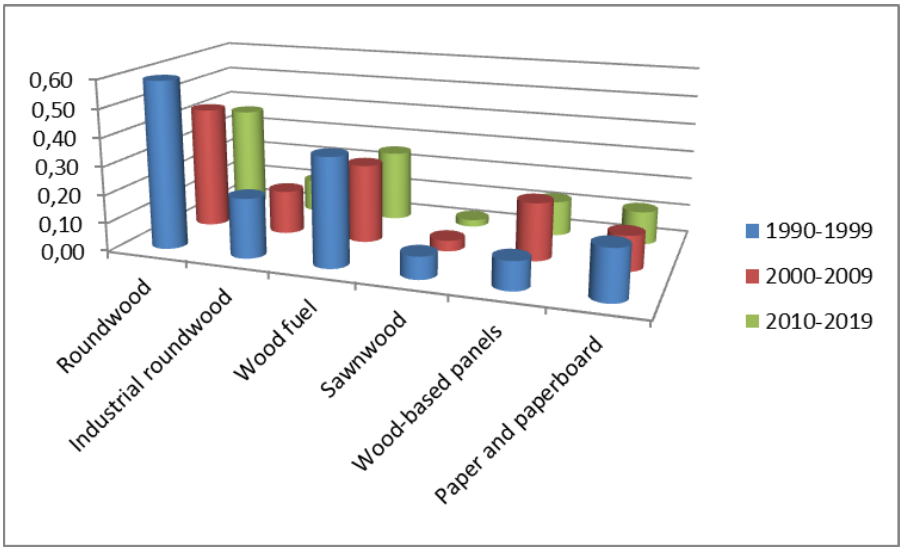


Figure 31. Mean production of wood products per ha of forest land in Greece

Pinus halepensis is not a species of major commercial importance, but it is a very important species in its native range, where its main uses are in agroforestry, soil conservation, erosion control, revegetation and land reclamation. It is not used for commercial forestry anywhere in the world, mainly because of its poor stem form and low-quality timber. *Pinus halepensis* yields a yellowish-brown, coarse-grained, resinous, moderately dense wood of poor quality which is sometimes used for rough constructional purposes, in low-grade joinery and boxes, as railway sleepers, telephone poles, mine props, also as a firewood and charcoal. Its use for wood products ranges as roundwood (pit props and posts) & sawn or hewn building timbers (carpentry/joinery, light construction, shingles, wall panelling).

Destination of *Pinus brutia* in wood products is for roundwood (building poles, pit props, posts, transmission poles), sawn or hewn building timbers (carpentry/joinery and for light construction), wood-based materials (fibreboard and hardboard).

In terms of the pilot sites of Isenli & Rhodopi, as typical marginal lands in Greece, and given the market trends and demands of the country we assume that only the conifer plantings of Isenli forest will be exploited for roundwood harvest. Of this harvest it is estimated that 50% will be destined towards industrial roundwood processing for wood-based panels while the rest 50% will head to the industry of pellets for fuel.

5.2.3 Poland

- Production of forest product categories (in total)

In terms of the countries that participate in the ***MAIL*** project, Poland has the second largest mean production of wood products considering the area of its forest land, following Germany. Wood harvest from forests and round wood production has been increasing steadily over the last 30 years in Poland with most of it heading at the industrial roundwood industry with wood fuel market being extremely small (Table 84, Table 85).

Table 84. Production (in million cubic meters) and participation (in %) of industrial roundwood & wood fuel in the roundwood production for the period 1990-2019 in Poland (source FAOSTAT-Forestry database)

Production per wood product category	Unit	Time period		
		1990-1999	**2000-2009**	**2010-2019**
Roundwood	(10^6m^3)	221.44	283.64	410.35
Industrial roundwood	(10^6m^3)	193.22	253.50	359.24
	%	*87.25*	*89.37*	*87.54*
Wood fuel	(10^6m^3)	28.23	30.14	51.11
	%	*12.75*	*10.63*	*12.46*

Table 85. Production (in million cubic meters) of the three semi-finished wood product commodity classes for the period 1990-2019 in Poland (source FAOSTAT-Forestry database)

Production per wood product category	Unit	Time period		
		1990-1999	2000-2009	2010-2019
Sawnwood	($10^6 m^3$)	41.24	33.12	46.76
Wood-based panels	($10^6 m^3$)	24.14	56.97	97.11
Paper and paperboard	(tn)	13.54	23.51	43.25
	($10^6 m^3$)	15.04	26.12	48.06

- Mean production of wood products per ha of forest land

Mean production of wood products per ha of forest land in Poland shows a steady production in the three semi-finished wood product commodity classes over the past 30 years (Table 86).

Table 86. Mean production of wood products per ha of forest land in Poland considering forest land changes per time period (source FAOSTAT-Forestry database

Mean production of wood products per ha of forest land ($10^6 m^3/ha$)	Time period		
	1990-1999	2000-2009	2010-2019
Roundwood	2.44	3.38	4.33
Industrial roundwood	2.13	3.02	3.79
Wood fuel	0.31	0.36	0.54
Sawnwood	0.46	0.39	0.49
Wood-based panels	0.27	0.68	1.02
Paper and paperboard	0.17	0.28	0.51

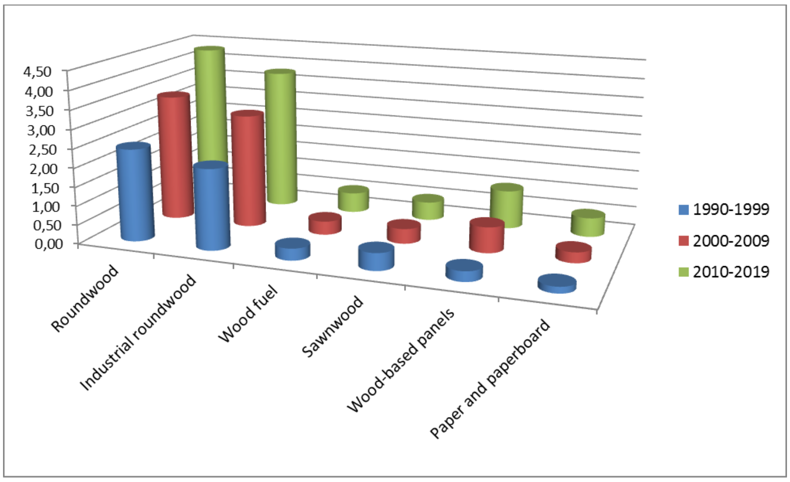


Figure 32. Mean production of wood products per ha of forest land in Poland

5.2.4 Spain

- Production of wood product categories (in total)

Spain presents a stable production of roundwood from forest harvest and its destination is mainly targeted at industrial roundwood. Semi-finished product categories of paper and paperboard as well as wood-based panels are the most prominent destinations of the harvested wood.

Construction plays a key role in the Spanish wood product demand and is the key market driver for sawnwood, added-value goods, fibreboard, particleboard, plywood and veneer sheets (Table 87, Table 88).

Table 87. Production (in million cubic meters) and participation (in %) of industrial roundwood & wood fuel in the roundwood production for the period 1990-2019 in Spain (source FAOSTAT-Forestry database)

Production per wood product category	Unit	Time period		
		1990-1999	2000-2009	2010-2019
Roundwood	($10^6 m^3$)	150.8	138.75	166.57
Industrial roundwood	($10^6 m^3$)	127.01	120.38	131.12
	%	*54.22*	*86.76*	*78.72*
Wood fuel	($10^6 m^3$)	23.79	18.37	35.45
	%	*15.78*	*13.24*	*21.28*

Table 88. Production (in million cubic meters) of the three semi-finished wood product commodity classes for the period 1990-2019 in Spain (source FAOSTAT-Forestry database)

Production per wood product category	Unit	Time period		
		1990-1999	2000-2009	2010-2019
Sawnwood	(10^6m^3)	30.15	31.12	22.23
Wood-based panels	(10^6m^3)	26.69	41.03	35.03
Paper and paperboard	(tn)	36.72	50.75	61.88
	(10^6m^3)	40.8	56.39	68.76

- Mean production of wood products per ha of forest land

Mean production of wood products per ha of forest land in Spain presents steady trends, with the wood fuel market being small (Table 89).

Table 89. Mean production of wood products per ha of forest land in Spain considering forest land changes per time period (source FAOSTAT-Forestry database)

Mean production of wood products per ha of forest land (10^6m^3/ha)	Time period		
	1990-1999	2000-2009	2010-2019
Roundwood	0.88	0.83	0.90
Industrial roundwood	0.74	0.72	0.71
Wood fuel	0.14	0.11	0.19
Sawnwood	0.18	0.19	0.12
Wood-based panels	0.16	0.25	0.19
Paper and paperboard	0.21	0.30	0.33

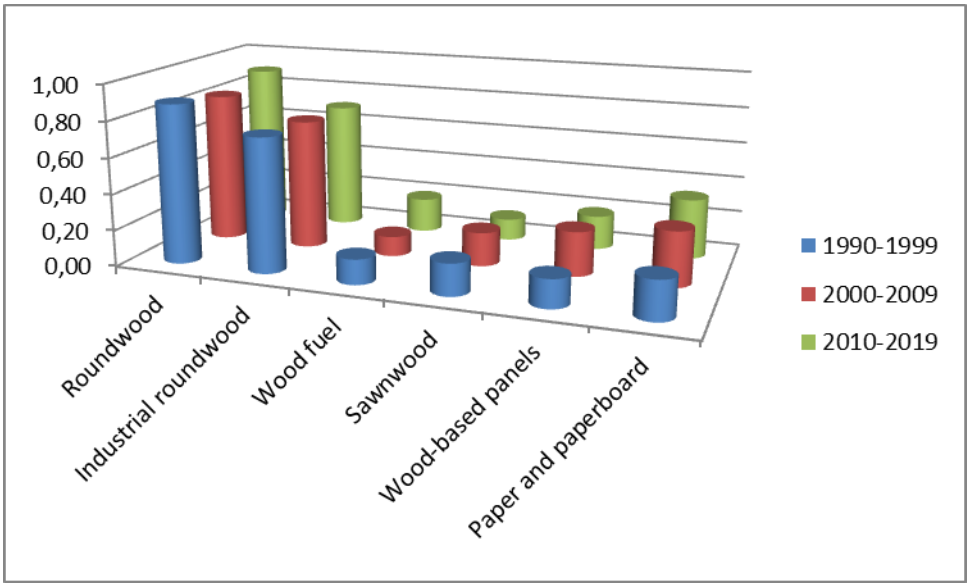


Figure 33. Mean production of wood products per ha of forest land in Spain

Common uses for *Pinus sylvestris* are for containers (boxes, cases, pallets), pulp (short-fibre pulp), roundwood (building poles, pit props, posts, roundwood structures, transmission poles), sawn or hewn building timbers (bridges, engineering structures, exterior fittings, for heavy and light construction), wood-based materials (composite boards, fibreboard, improved wood, laminated wood, medium density fibreboard, particleboard), woodware (industrial and domestic woodware, marquetry, musical instruments, sports equipment, turnery, wood carvings).

Wood products from *Pinus nigra* fall in categories of pulp (long-fibre pulp & short-fibre pulp), sawn or hewn building timbers for heavy construction and wood-based materials (composite boards, fibreboard, particleboard and plywood).

5.3 Market study conclusions

The output of forestry comprises several activities; however, two dominate for most countries – wood in the rough (i.e. felled trees removed from the forest) and net annual increment (i.e. the growth of standing trees in managed forests, or in other words, forests available for wood supply) (Figure 33).

According to the rules of National accounts, the growth of trees in managed forests is considered to be an output of economic activity and, as a result, it is included in the total output of the industry. In 2018, available data suggest that the output of wood in the rough (logs) was highest in Germany, Sweden and France with 4 736, 4 323 and 2 827 million euro respectively. The net increment of forest trees in managed forests was highest in Sweden (EUR 3 424 million), followed by Germany (EUR 2 808 million) and France (EUR 2 637 million). On the other hand, the output of non-wood forest products ranged from EUR 332 million in Portugal (the main producer of cork in the world), EUR 242 million in Poland and EUR 186 million in Czechia to EUR 0.6 million in Bulgaria. The category "Other", which includes services, secondary activities and other products, showed the highest output in France (EUR 1 427 million) followed by Germany (EUR 1 213 million) and Sweden (EUR 1 034 million).

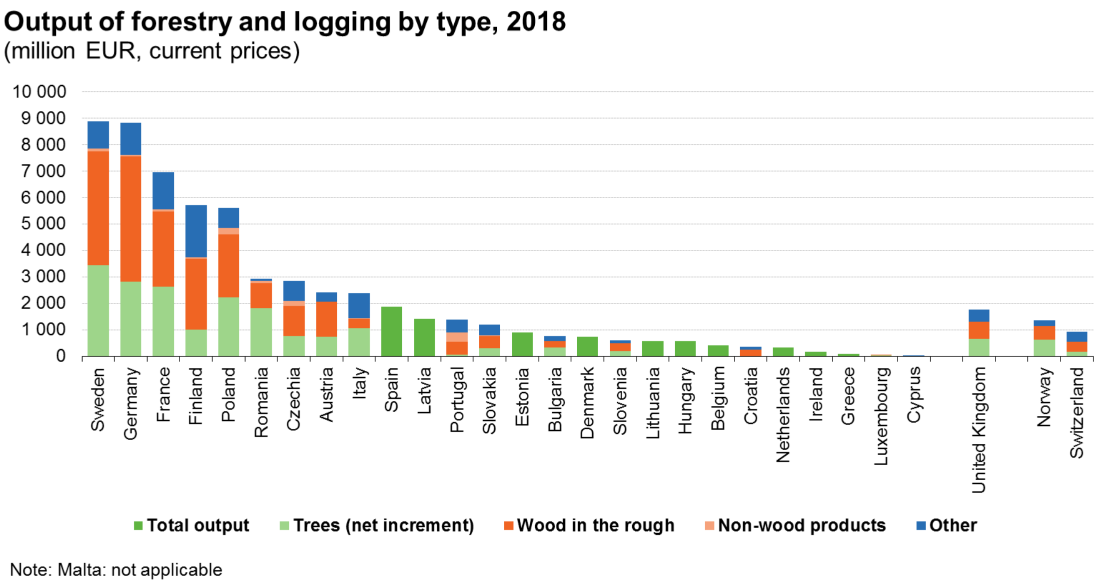


Figure 34. Output of forestry and logging by type.

6. SUMMARY AND CONCLUSIONS

As already described harvested timber can be converted into a wide range of wood products where the carbon content moving through different levels during their life cycle. After their original use, wood products may become recycled, and ultimately burned or deposited in landfills where they slowly decay. The carbon stored in wood, which was initially captured from the atmosphere, is finally released back into the atmosphere. Changing the demand for wood products can consequently have an important role in the global carbon cycle and the fight against climate change.

In this deliverable and for the four Member States the categories of wood products that can come from afforestation projects at the Pilot Sites' marginal lands were selected that are detected through the ***MAIL*** T2.3 algorithm.

Based on results of T4.2 and the different mixture proportions of proper species for each pilot site according to ecological factors, the carbon stock that is stored in harvested wood products was calculated during their lifetime.

The carbon stored in HWP depends greatly on the lifespan of the HWP, which is determined by their type (e.g. pulp, wood chips, wood panels or sawn wood). The type of marginal land (high or low suitability for plantings) affects the amounts of HWP, as well as the time of their harvest, which may be carried out later in areas with lower SI, as in the case of Spain.

In cases where only short-lived products are expected to be harvested (e.g. Greece), the forest established acts as a carbon sink until the final cut and is then converted to a carbon source since the HWP result in emissions shortly after their harvest. In the case of Spain, where wood-based panels and sawn wood could potentially be harvested from MLs, at least 1 ton C/ ha of harvested woodland can continue to be stored in HWP for approximately 200 years after the final cut.

On the cases of the Germany and Poland site is clear that the sawnwood products will stock higher value of carbon, once it has considerable production, besides that, the species with higher carbon stocked was the *Quercus* and *Picea abie,* which is also directly related with the amount of that species that will be planted on that area, showing also that based on the wood products from this areas, at least 1 ton C/ha can continue stored for approx. 700 years after the final cut.

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ANNEX I: TABLE OF FIGURES

ANNEX II: LIST OF TABLES

ANNEX III: CUBIFOR ANALYSIS RESULTS FOR SPAIN

HWP (m^3/ha) per species, SI and age produced after each thinning and after the final clear cut (Source: CubiFOR v2.0)

Species	SI	Treatment	Age	Harvested Wood Products (m^3/ha)			
				V_Fuste	V_Trit	V_Canter	V_Sierra
				Stem volume	Wood chips & particles	Wood based panels	Sawn wood
Pinus nigra	*12*	*1st thinning*	45	45.93	43.23	0.00	0.00
Pinus nigra	*12*	*2nd thinning*	60	70.63	26.73	43.51	0.00
Pinus nigra	*12*	*3rd thinning*	75	77.67	21.51	55.35	0.00
Pinus nigra	*12*	*Final clear cut*	85	277.14	24.34	251.83	0.00
Pinus nigra	*15*	*1st thinning*	40	70.75	69.89	0.00	0.00
Pinus nigra	*15*	*2nd thinning*	55	101.95	22.36	75.57	0.00
Pinus nigra	*15*	*3rd thinning*	70	98.61	20.13	77.77	0.00
Pinus nigra	*15*	*Final clear cut*	80	361.17	23.50	0.00	336.74
Pinus sylvestris	*12*	*1st thinning*	40	29.15	26.90	0.00	0.00
Pinus sylvestris	*12*	*2nd thinning*	55	48.48	27.12	20.95	0.00
Pinus sylvestris	*12*	*3rd thinning*	70	41.95	11.96	28.81	0.00
Pinus sylvestris	*12*	*Final clear cut*	110	239.67	14.28	0.00	222.04
Pinus sylvestris	*15*	*1st thinning*	35	38.77	33.66	0.00	0.00
Pinus sylvestris	*15*	*2nd thinning*	50	64.78	37.33	24.16	0.00
Pinus sylvestris	*15*	*3rd thinning*	65	61.44	12.96	46.67	0.00
Pinus sylvestris	*15*	*Final clear cut*	110	328.28	27.36	0.00	299.59
Pinus pinaster	*12*	*1st thinning*	40	33.57	32.62	0.00	0.00
Pinus pinaster	*12*	*2nd thinning*	50	48.51	48.18	0.00	0.00
Pinus pinaster	*12*	*3rd thinning*	65	45.69	5.26	38.32	0.00
Pinus pinaster	*12*	*Final clear cut*	80	233.34	13.59	0.00	217.23
Pinus pinaster	*15*	*1st thinning*	35	43.83	40.00	0.00	0.00
Pinus pinaster	*15*	*2nd thinning*	45	67.33	38.84	24.52	0.00
Pinus pinaster	*15*	*3rd thinning*	60	86.74	10.37	76.07	0.00
Pinus pinaster	*15*	*Final clear cut*	75	329.63	16.07	0.00	308.54
Pinus halepensis	*11*	*1st thinning*	20	0.00	0.00	0.00	0.00
Pinus halepensis	*11*	*2nd thinning*	30	0.00	0.00	0.00	0.00
Pinus halepensis	*11*	*3rd thinning*	40	0.00	0.00	0.00	0.00
Pinus halepensis	*11*	*4th thinning*	50	0.60	0.50	0.00	0.00
Pinus halepensis	*11*	*5th thinning*	60	4.66	4.22	0.00	0.00
Pinus halepensis	*11*	*6th thinning*	70	4.57	3.71	0.00	0.00
Pinus halepensis	*11*	*7th thinning*	80	4.25	4.11	0.00	0.00

Pinus halepensis	*11*	*8th thinning*	90	3.71	3.47	0.00	0.00
Pinus halepensis	*11*	*9th thinning*	100	3.21	2.91	0.00	0.00
Pinus halepensis	*11*	*10th thinning*	110	2.77	2.46	0.00	0.00
Pinus halepensis	*11*	*Final clear cut*	120	145.22	42.47	99.21	0.00
Pinus halepensis	*14*	*1st thinning*	20	0.00	0.00	0.00	0.00
Pinus halepensis	*14*	*2nd thinning*	30	0.00	0.00	0.00	0.00
Pinus halepensis	*14*	*3rd thinning*	40	6.54	6.09	0.00	0.00
Pinus halepensis	*14*	*4th thinning*	50	1.22	1.17	0.00	0.00
Pinus halepensis	*14*	*5th thinning*	60	11.94	10.68	0.00	0.00
Pinus halepensis	*14*	*6th thinning*	70	10.54	10.25	0.00	0.00
Pinus halepensis	*14*	*7th thinning*	80	9.19	8.71	0.00	0.00
Pinus halepensis	*14*	*8th thinning*	90	7.79	7.76	0.00	0.00
Pinus halepensis	*14*	*9th thinning*	100	6.63	4.29	2.24	0.00
Pinus halepensis	*14*	*10th thinning*	110	5.53	3.57	1.82	0.00
Pinus halepensis	*14*	*Final clear cut*	120	234.96	18.19	209.54	0.00